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Volume 01 Number 01 January-June 2019

Insight

Cambodia Journal of Basic and Applied Research (CJBAR)

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Insight

Cambodia Journal of Basic and Applied Research (CJBAR)

Volume 1, Number 1, January—June 2019

Access to online publication: www.rupp.edu.kh

E-mail: **cjbar.rupp@gmail.com**

English copy editing: Simon ROSS

Cover design: Lim Mengchhay

Photo credit: Shekhar ATHAVALE

Printed in Phnom Penh, Cambodia

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

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Editorial: The internationalization of higher education in Cambodia

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To cite this article: Chet, C. & Un, L. (2019) The internationalization of higher education in Cambodia. *Cambodia Journal of Basic and Applied Research (CJBAR), 1(1)*, 05–14.

In the era of globalization, the internationalization of higher education institutions (HEIs) has become a prevailing trend (Hong, 2018). A global commitment to take advantage of this trend to reduce disparities in educational quality between developed and developing countries was endorsed at the World Conference on Higher Education (WCHE) (UNESCO, Paris, 5-8 July 2009). An important driver towards this aim has been the development of education policies in Asian countries with rising populations, such as India, the People's Republic of China, Indonesia, and Malaysia focused on HEI internationalization. Other countries in the region such as Singapore, Australia, Hong Kong and Malaysia have responded to these policies by transforming themselves into international and regional hubs for higher education, exporting education services to neighbouring countries such as India, Indonesia, Taiwan, Thailand, Vietnam and South Korea (Ng, 2012). Global demand for higher education services is rapidly increasing. Asian countries will represent 70% of this demand by 2025. The booming economies of China and India are key drivers of this growth, representing over half of the demand from Asia (Bohm et. al., 2002). At the same time, the internationalization of HEIs is playing a role meeting socio-economic development needs in each country in light of globalization trends (Qiang, 2003).

Knight (1993) refers to this process as 'integrating an international or intercultural dimension into the teaching, research and service functions of HEIs'. However, in practice, it also represents the commercialization of research and postsecondary education. There is increasing global competition for the recruitment of foreign students among wealthier countries as they seek to build an international reputation for the provision of higher education services as a way of generating export revenue (Ibid.).

In Cambodia, there has been a remarkably strong international influence on local HEIs since the end of a prolonged civil war in the 1990s. Since the fall of the Khmer Rouge in 1979, a period of transitional government under the United Nations Transitional Authority in Cambodia (UNTAC), and the signing of the 1991 Paris Peace Agreements, the Royal Government of Cambodia has gradually increased its engagement with market-driven regional and international integration as a tool of socio-economic development. As a result, institutional teaching and research partnerships between HEIs in Cambodia and other countries have also gradually increased.

Howes & Ford (2011) describe both opportunities and challenges for HEIs in Cambodia related to this change. The most challenging aspect has been harmonizing or integrating foreign influences with local higher education needs. The number of HEIs in Cambodia has increased remarkably: from 14 in 1998; to 97 in 2012; and 121 in 2017 (MoEYS, 2017). Over 80% of these institutions have been established in the last 15 years. This has had critical implications for the quality of higher education services in Cambodia (Sen, 2013). In response, the Ministry of Education Youth and Sport (MoEYS) developed the Education Strategic Plan 2014-2018 focused on developing the human resources in Cambodia required to transition from a lower-middle income country to an upper-middle income country by 2030, and a developed country by 2050 (MoEYS, 2014a). Additionally, the Policy on Higher Education (2030) has established a long-term vision of building a quality higher education system that produces excellent knowledge, skills, and moral values for working and living in an era of globalization and a knowledge-based society (MoEYS, 2014b).

There is no doubt that the internationalization of HEIs is an important factor in developing the human resources required to meet Cambodia's future labor market needs. However, to date, only a few HEIs in Cambodia have had the capacity to participate in the international higher education sector. The oldest and largest academic institution in Cambodia, the Royal University of Phnom Penh (RUPP), is one institution that has been able to take advantage of improved academic standards through international cooperation (see Figures 1 & 2). In an era where globalization and the information economy has increasing influence, it has become important to move toward a knowledge-based society, where socio-economic development is planned and harmonized internationally. The internationalization of HEIs will play a key role in this change in Cambodia through: (1) the internationalization of the curriculum, where international standards are applied to course content; (2) proficiency in foreign languages, enabling cross-cultural exchange; (3) the internationalization of research efforts through collaborative research between national and foreign institutions; and (4) internationalization by extension, where the administrative functions of HEIs are benchmarked to international standards (Barragan Codina & Leal López, 2013).

Internationalization forms part of RUPP's strategic plan to enable the institution to compete both regionally and globally. Achieving international standards for higher education is an important prerequisite for meeting local needs for socio-economic development. The International Relations Office (IRO) at RUPP has implemented this agenda through improving communication channels with international partners. RUPP has collaborated with other universities globally through: (1) student exchange programs, (2) foreign language training, (3) exchange programs for academic and administrative staff, and (4) engaging with programs designed to improve education and research output, such as: international collaboration on research projects; participating in international symposiums, seminars, and meetings; as well as sharing information through articles published in international peer-reviewed journals.

To date, RUPP has international partnerships with 147 HEIs across 20 countries (Figure 3). The highest proportion of these partnerships (24.5%) is in Japan, followed by South Korea (17.0%), China (12.9%), Thailand (10.9%), France (5.4%), Vietnam (5.4%), and the USA (4.8%). Moreover, in 2017, RUPP supported 1,306 students to participate in international exchange programs.

As a result, 497 international students from 18 countries studied at RUPP, while 809 Cambodian students from RUPP studied in 20 countries in regions across the globe, with the support of financial assistance from international HEI partners. Faculty members across all RUPP faculties cooperate internationally to conduct research in the science and the humanities focused on both the Cambodian, regional, and international context. Presenting at international conferences has provided benefits to RUPP faculty members and students such as increasing their breadth of knowledge, professional engagement with associates with different social and cultural values, and the development of mutually-beneficial relationships between Cambodia and other nations.

Figure 1. International students studying at RUPP

Figure 2. RUPP students on exchange to other countries

Source: RUPP, 2017

Figure 3. RUPP's international partnerships

Source: RUPP, 2017

Yun (2014) has outlined how internationalization activities are supporting RUPP to modernize its academic standards. Yet, various challenges including the lack of a comprehensive strategy for international partnerships, a lack of financial resources, and a lack of appropriate skills and knowledge have limited the effectiveness of these policies. To address these challenges, Chet (2009) has suggested that higher education reforms are required in relation to the financing and governance of Cambodian HEIs including international accreditation, an improved curriculum, and technological innovation.

In 2019, RUPP will aim to develop new international partnerships with universities in China, Europe, and the USA. The accessibility of Cambodian education services to international students will be improved through initiatives such as English language delivery of courses in a range of disciplines. Other activities aimed at building an enabling environment for collaborative research with world-class universities will also be implemented. RUPP will encourage faculty members to conduct activities focused on developing international partnerships, such as organizing field trips to Cambodia for international students, as well as participating in international conferences and training events. The internationalization strategy of the RUPP is about much more than developing Memoranda of Understanding with international HEIs. International collaboration will help RUPP to establish an environment where mutually beneficial international partnerships are created that enhance the socio-economic development of Cambodia.

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Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Preliminary research on insect diversity at Kulen Promtep Wildlife Sanctuary, Cambodia

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Cambodian insect fauna is virtually unstudied, especially compared to the extensive research completed on vertebrate biodiversity and conservation management. Kulen Promtep Wildlife Sanctuary (KPWS) in Preah Vihear province is one of the best examples of biodiverse habitats in Cambodia, including endangered and rare species such as *Thaumatibis gigantea* (the giant ibis). The study aims to: (1) conduct a preliminary insect survey at KPWS; (2) document species composition and the distribution of insect biodiversity across various habitat types; and (3) identify the insect species sampled and classify them in a database of insect fauna present at KPWS with references to new Cambodian species. An insect survey in KPWS was conducted between the 12th and 21st of October 2017 across six survey sites, where 775 insect specimens were collected comprising 12 orders, 53 families, and 147 morphospecies. The three dominant orders sampled were *Coleoptera* (beetles), *Hemiptera* (true bugs) and *Lepidoptera* (butterflies and moths). An analysis of the species diversity showed that the insect community at KPWS is abundant and evenly distributed within a Shannon's diversity index and Shannon's equitability value of H = 4.20694 and E_H = 0.85, respectively. The study also found the richness of insect species at KPWS is supported by the availability of different habitat types endemic to the region, including deciduous dipterocarp and dry evergreen forests.

Keywords: Kulen Phromtep Wildlife Sanctuary, entomology, insect survey, species diversity, habitat.

To cite this article: Phauk, C., Rim, S., Keath, S., Keum, T., Doeurk, B. & Hot, C. (2019) Preliminary research on insect diversity at Kulen Promtep

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Introduction

Cambodian insect fauna is virtually unstudied, especially compared to the extensive research conducted on vertebrate biodiversity. This oversight poses a problem as insects comprise a much higher proportion of total of global biomass than vertebrates, constitute irreplaceable components of ecosystem processes, and are vital for ecosystem health and function. In Cambodia, biodiversity has been seriously affected by many drivers, including deforestation, illegal logging, and climate change. Significant habitat loss in the country for many taxa has caused some species populations to decline, while others have become endangered or extinct. However, the impacts on insect diversity in Cambodia are largely unknown, as little research specific to insects has been conducted.

Globally, forests cover almost 30 % the land area on Earth and support 80 % of total terrestrial biomass by providing habitat for enormous number of plant and animal species (Morales-Hidalgo et al., 2015). In 2000, the FAO estimated that there was 1803 million ha of tropical forests, with 49% of these forests in tropical America, 34% in tropical Africa and 16% in tropical Asia; however, at this time, between 25 and 50% of the world's tropical forest had already been converted to other land-uses (Lewis, 2005). In Cambodia, the Royal Decree on the Protection of Natural Areas in Cambodia (1993) defined 23 Protected Areas across four categories, including natural parks, wildlife preserves, protected scenic view areas, and multipurpose areas (ICEM, 2003 & Souter et al., 2016). When the revised Protected Areas Law (2008) was promulgated, a further four categories were also defined including Ramsar sites, biosphere reserves, natural heritage sites, and marine parks. The number of Protected Areas increased in Cambodia increased to 31 at this time (MoE, 2009).

Species diversity of Cambodian insects has received little attention in academic literature. However, several threats to insect biodiversity in the country clearly demonstrate a need for this knowledge. Kulen Promtep Wildlife Sanctuary (KPWS) is Cambodia's largest wildlife preserve, comprising 402,500 hectares of protected ecosystems (ICEM, 2003 & Frontier, 2012). The sanctuary is now part of the Prey Preah Roka National Park, which is the largest evergreen and semi-evergreen forest in the Northern Plains of Cambodia. This area was set aside in 1964 by King Norodom Sihanouk to protect critically endangered and possibly extinct national animals. It is of exceptional importance for biodiversity conservation as the largest remaining extensive, intact block of a unique ecosystem that once dominated most of the Indochina region. It is situated across Siem Reap, Preah Vihear and Oddor Meanchey provinces, bordering Thailand and Laos (ICEM, 2003). Currently, it is the largest protected area in Indochina (Frontier, 2012). KPWS comprises vital habitat for rare bird species such as *Thaumatibis gigantean (*the giant ibis) and other critically endangered, possibly extinct species such as *Bos sauveli* (the Kouprey) (Edwards, 2012), which is dependent on the preservation of habitat in the sanctuary including lowland forests and swamp.

Currently, there are no recent records available of catalogued insect species lists for KPWS. Thus, a preliminary study is required to support a verity distribution of species diversity for insects in the protected area. In Cambodia, very few entomological or insect biodiversity surveys have been documented especially compared with volume of research conducted on species of vertebrates and plants. The few examples include, the Cambodian Journal Natural History, which has documented some insect orders, such as *Odonata* (dragon and damselflies) and *Lepidoptera* (butterflies and moths) (Roland et al., 2010); and the Cambodia Entomology Initiatives (CEI), which has documented other insect species including a study recording 82 species of bees in Cambodia (Ascher et al., 2016). More recently, a cooperative citizen science project, using Facebook and the Fulgoromorpha Lists On the Web (FLOW) website recorded 17 species of lantern fly, 12 of which had not previously been recorded Cambodia (Constant et al., 2016). However, these results are not comprehensive, nor are they representative of the insect diversity present at KPWS or in Cambodia. Insects are the most diverse group taxa with nearly one million species described globally and many more that are yet to be documented (Michael et al., 2010).

Thus, research on insect diversity is of high importance in Cambodia. A preliminary insect survey at the KPWS will enable enhanced knowledge, which will enable insect species specific to Cambodia to be identified. The specific aims of this study are to (1) conduct a preliminary insect survey at KPWS; (2) document the species composition and distribution of insect biodiversity in various habitat types; and (3) identify the insect species collected in the survey and classify them in a database of insect fauna present at KPWS with references to new Cambodian species.

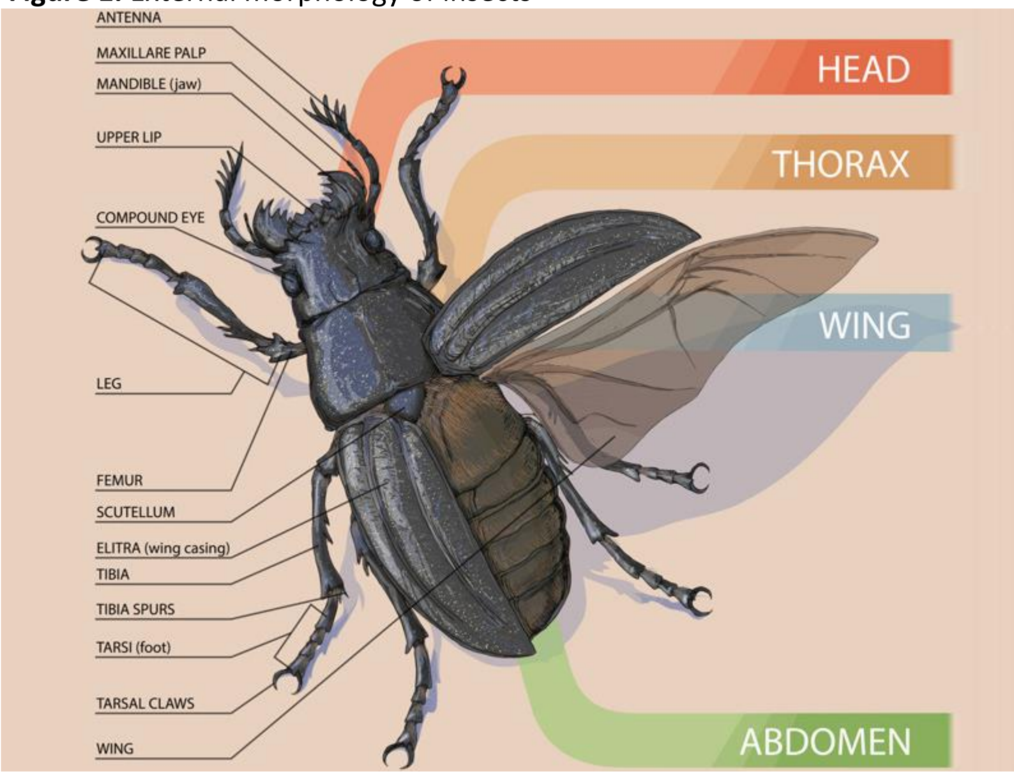
Benefits of understanding local insect biodiversity

Insects are most diverse group of organisms on earth (Thomas, 2005). They are the most dominant terrestrial group and occur in all global ecosystems. Insects have been present on the planet for more than 350 million years and almost one million species have been described. Many species are yet to be identified or documented (Martin, 2012). Insect biodiversity provides vital ecosystem services such as pollination, providing raw materials for commercial products and medicines, and supporting scientific research (Borror et al., 1981). Insects have adapted to life in almost every type of habitat and have developed a broad range of unique functions (Borror et al., 1981; Triplehorn & Johnson, 2005). Understanding insect biodiversity is of high importance. For example, some insect taxa can feasibly be used as an indicator of habitat loss to related to the dynamics of climate change (Holt & Miller, 2010). Additionally, the capacity to accurately identify and characterize the behavior of insects, such as the *Membracidae* (treehopper) family, which feed on moisture contained within important crops, such as rice, is another benefit. This type of knowledge has the potential to mitigate the loss billions of dollars of agricultural production annually, through the development of strategies to prevent physical crop damage and the transmission of plant pathogens (Conti, 1985; Marmarosch and Harris, 1979). Knowledge of insect biodiversity may also be used to identify model organisms to be used in studies to better understand ecological processes or evolutionary behavior. This is important for efforts to conserve endangered species at risk due to degraded habitats (Biedermann et al., 2005; Dietrich, 2009).

Despite these benefits, insect surveys conducted by entomologists are rare in Cambodia, especially compared to vertebrate studies. There is an urgent need to improve the level of knowledge of local taxa for insect fauna in the region. KPWS is a significant site for research of insect biodiversity and thus important for the Cambodian National Strategy for Science and Technology (UNESCO, 2010). The study of insect biodiversity in frontier areas, such as KPWS, also has other benefits. For example, insect biodiversity indicators can assist with the monitoring of illegal activities, such as logging, or slash and burn agriculture. It can also act as a preliminary step for studying other animal species. For example, the Northern Plains of Cambodia are home to many internationally significant bird species, including the critically endangered *Asarcornis scutulata* (white-winged duck), which is in decline due to habitat loss (WCS, 2017). Knowledge of the dynamics of insect populations and their habitats may also help to plan conservation programs for other species such as *Urocissa erythroryncha* (the red-billed blue magpie), *Melogale personata* (large-toothed ferret badger), *Hylobates pileatus* (pileated gibbon), *Macaca fascicularis* (long-tailed macaque), and other endangered species (personal communication, Ben Davis, 2015).

Insects are group of invertebrates with six legs and either one or two pairs of wings (Snodgrass, 2015; Cranshaw & Redak, 2013 & Triplehorn & Johnson, 2005). Their body is divided into three parts, a head, thorax and abdomen (Figure 1). The head of an insect is a feeding and sensory center; bearing an antennae, eyes and a mouth. The eyes of an insect are either simple (ocelli) or compound and made up of a large number of individual lenses. The mouth of an insect comprises a labrum or upper lip; a pair of main jaws, or mandibles; a pair of secondary jaws, or maxillae; and a labium, or lower lip (Borror et al., 1981). These mouthparts are often specific to various types of insect groups and are linked to a habitat and diet. Mouthparts are one major way of distinguishing between different insect orders. For example, all *Coleoptera* (beetles) have chewing mouthparts, whereas *Hemiptera* (true bugs) have a piercing, sucking tube.

Figure 1. External morphology of insects



Source: Animal World: Discovery the world of animals[1]

The thorax, or middle segment of the body, is made up of three segments: the prothorax, mesothorax and metathorax. Each segment bears a

[1] http://www.animalsworlds.com/insect-anatomy.html

pair of legs. In flying insects, the second and third segments also bear a pair of wings. The wings of an insect have an upper and a lower membrane. The area between each membrane is strengthened by a framework of chitinous tubes or veins. The abdomen, or end segment of the body of an insect is its metabolic and reproductive centre, where food is digested and excreted and where reproductive organs are located. Most insects breathe through fine air tubes called tracheae that are opened at the abdomen by a pair of breathing pores, or spiracles. Reproductive systems often have specific structures, which vary across different species (Borror et al., 1981 and Cranshaw & Redak, 2013).

Insect orders such as *Coleoptera* (beetles), *Diptera* (flies), and *Lepidoptera* (moths) go through morphologically different stages in their life cycle. Immature insects (larvae) hatch from eggs, usually in the form of a caterpillar, grub, or maggot and pass through a major physical change, called metamorphosis, before reaching an adult stage. Each stage of maturing is called an instar. An insect that is about to metamorphose usually goes through a resting stage called a pupa. When the change is complete, an adult insect emerges. However, other insect species such as *Blattodea* (cockroaches), *Hemiptera* (true bugs), and *Orthoptera* (crickets and grasshoppers) go through a nymphal stage (instar), where they appear as tiny versions of an adult. The main difference being that the adult has fully functional wings, however, this is not always true.

Study area and methodology

The collection of insect specimens was conducted at several survey sites within and bordering KPWS in Preah Vihear. These activities were conducted in two major locations across three districts, including (1) Choam Ksant; (2) Kuleaen; and (3) Sangkum Thmei. These areas included degraded forest, semi-evergreen forest, and tropical rainforest. The activities described were conducted over ten days in October 2017. The coordinates of each of the six survey sites are shown in Table 1 and their location has been identified on a map (Figure 3).

Research at the two of the study areas (Choam Ksant and Kulean) was conducted between the 12th of 16th of October, 2017. Both of these locations are within KPWS (Figure 2). Five specific survey sites were selected for completing the survey, representing a range of habitat types:

- CA0094 is close to Takeung station and the National Road. It is surrounded by deciduous dipterocarp forest and samples at this site were collected from areas near households including grassland habitats with sparsely populated trees, as well as rice fields, near a stream.
- CA0095 is close to Tmart Peuy village and surrounds an area of deciduous dipterocarp forest. At the site there are houses owned by villagers approximately 3 km from the main road. Other habitats present include grassland, agricultural land and wetlands.
- CA0096 is also near Tmart Peuy village. It is surrounded by deciduous dipterocarp forest and here includes wetland and patchy grassland habitats.
- CA0097 is close to Takeung Station and surrounded by deciduous dipterocarp forest. Samples from here were collected near households, in rice fields, near a stream, as well as from grassland along a small road.

- CA0098 is close to Trorpeang Preng village and is also surrounded by deciduous dipterocarp forest. Samples from this site were taken from grassland habitats with small shrubs, as well as areas deep in the forest, more than 10 km from the main road.

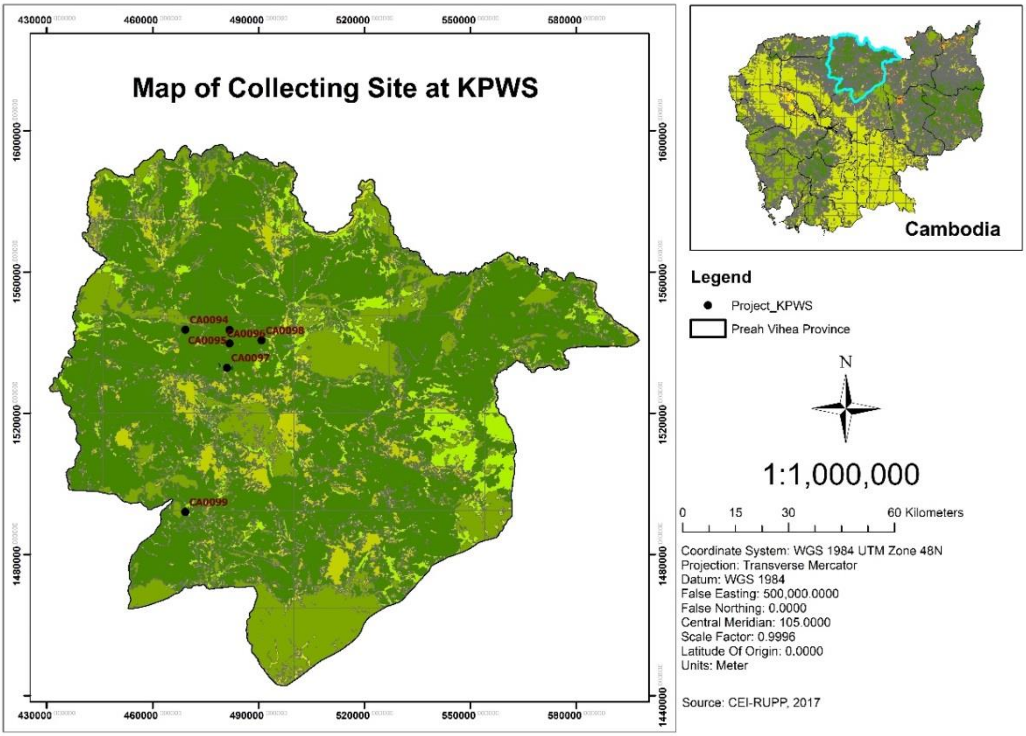
Table 1. Coordinates of survey sites at *KPWS* and *Phnom Tnout Community Forest*

Code sites	Latitude	Longitude
CA0094	N13°53.490’	E104°49.915’
CA0095	N13°57.782’	E104°49.915’
CA0096	N13°55.695’	E104°51.279’
CA0097	N13°51.963’	E104°49.506’
CA0098	N13°56.163’	E104°54.922’
CA0099	N13°29.798’	E104°42.953’

An additional insect survey was conducted at a third study area comprising just one survey site. It was managed by a ecotourism operator called ‘Be Treed adventures’ in the Phnom Tnout community forest, which is currently under consideration as a protected forest. The survey occurred between the 16th and 21st of October. The community forest is 6,400 hectares and located approximately 58 km outside of the KPWS. However, the area contains many endangered and threatened species including the *Bos javanicus* (benteng) and *Hylobates pileatus* (pileated gibbon). The survey site is described as follows:

- CA0099: is an evergreen forest, near a water fail and temple in a mountainous area. The weather at this site was more humid than the other sites surveyed.

Figure 2. Survey sites at *KPWS* and *Phnom Tnout Community Forest.*



Source: Cambodian Entomology Initiatives, 2018

KPWS comprises mainly deciduous dipterocarp forest. The insect survey was conducted in these areas, as well as focusing on other habitats such as open grasslands, rice fields, and rainforests, as well as aquatic environments such as streams, ponds and wetlands, as outlined in Figure 3. The collection of specimens was conducted between 9am and 5pm each day, and during the evening between 7pm and midnight. Samples were collected at random along forest paths. Insect specimens were collecting via several methods as outlined below (Figure 3). Photographs were taken using a high resolution camera (Canon EOS7D), with either a macro lens (Canon EF 100mm f/2.8) or macro lens (MPE 65 mm f/2.8) with a flashlight (Macro Ring Lite MR-14EX). Insect specimens less than 2cm in size, such as those from the *Hemiptera* (true bug) and *Diptera* (fly) orders were collected and preserved in test tubes with a 70% ethanol solution. Larger insect specimens of between 2cm and 20cmm were preserved in a killing box containing ethyl acetate ($C_4H_8O_2$). All specimens were transferred to the CEI laboratory of the Department of Biology at the Royal University of Phnom Penh. They were stored at a temperature below 0^oC awaiting future identification.

Figure 3. Habitat types at *KPWS* and *Phnom Tnout Community Forest* (October 2017)

Specimen collections method varied for different insects and different habitats For example, insect such as *Lepidoptera* (butterflies and moths) and *Odonate* (dragonflies) were primarily collected using sweep nets. However various types of traps, including light traps, malaise traps, and pitfall traps, were used for other species at *KPWS.* At *Phnom Tnout Community Forest* pitfall traps were used in addition to other types. The selection of equipment in each habitat was based the time of day and the type of insects observed. At night, samples were only collected using light traps or sweep nets. Pit traps were used at Phnom *Tnout Community Forest* as there was sufficient time available to use them effectively.

Hand collection (sweep nets)

A standard, coarse net was used around foliage to directly capture free-living insects; specific to certain taxa in calm, dry weather. The nets had a handle with a length of 1 m, enabling samples to be collected in heavy vegetation. Sweep nets were used to collect a wide range of insects; however, other traps were also used as sweep nets tend to be selective of insects that are easy to dislodge from their habitat. The collection of specimens by this method was standardized in grassland and rice fields by using a consistent length of the sweep. It was the primary method used to collect specimens from grassland and the foliage of trees. In dense forests, a short-handled net was used. When collecting *Lepidoptera* (moths and butterflies) specimens in treetops, it would have been possible to collect samples by hand, however, sweep nets were used as they tend to be less damaging to the specimen. A sweep net with a veil was used to collecting aquatic insect specimens from ponds and streams (Figure 4).

Malaise Traps

Large, mesh interception traps were used to capture a large number of flying insects over longer periods of time. However, as these traps are indiscriminate, they were not used in areas, where it was perceived that rare or threatened species may have been present. The method was particularly effective for orders of *Diptera* (flies) and *Hymenoptera* (wasps, bees, and ants). Malaise traps were found to be more effective in open areas and installed in high locations.

Light Traps

A broad variety of light trap designs are available. They were used in this survey to collect specimens with a tendency to be attracted to light, particularly UV light.

Figure 4. Collection methods used for the insect survey at *KPWS* and Phnom *Tnout Community Forest*. From left to right: (a) sweep nets (b) light traps (c) malaise-traps and (d) pit traps.

They were used both to retain live insects for classification before they are later released; and with a collection sheet, where the insects were killed. When collecting specimens using light traps, the weather conditions were taken into account, as well as size of the sample area, as these traps tend to attract species from a broad range. Light traps using lamps were primarily used at night to capture insect species such as *Orthoptera* (grasshopper) and *Hemiptera* (leafhoppers) near roads and other open areas.

Pitfall Traps

Pitfall traps were used to collect surface-moving insect specimens, which were captured by falling into containers sunken into the surface of the ground surface and then held awaiting later classification and/or preservation. They were constructed using a plastic box containing soup, salt, and water and held in the ground by the surrounding soil. The traps were used in open areas at *Phnom Tnout Community Forest* that were cleared of leaves and roots within a 50 cm of the trap. After a number of days, select specimens were collected and preserved in a 70% ethanol solution in a test tube.

Species Identification Specimens were mounted and categorized into orders and families of insect groups as shown in the Figure 5. They were classified using manuals, textbooks, and publications with specific reference to the order of insect specimens collected. Smaller specimens of less than 2 cm were examined using stereomicroscopes to assist with identification. High-resolution cameras with macro lenses were also used during fieldwork. The morphological characteristics of each specimen were used to identify the species based on specific characteristics, followed by morphospecies (Ascher et al., 2016; Borror et al., 1981; Ek-Amnuay, 2008 & Ek-Amnuay, 2012).

Statistical Analysis

Shannon's diversity index was used to characterize the species diversity of insects at KPWS. Diversity indices provide more detailed information about community composition than just the number of species

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present by taking into account the relative abundance of each species. Shannon's diversity index (H) at once provides a simple summary of the richness and evenness of a biological community. It increases as an indicator of abundance, as both variables increase. Typical values generally lie between 1.5 and 3.5 and are rarely above 4. Shannon's equitability value (E_H) is used to indicate the evenness of species in a community, where a value of 1 represents a community that is very evenly distributed, where no one species dominates.

Figure 5. Specimens mounted into boxes categorizing specific groups

Findings and Results

Insect specimens collected from KPWS show a high level of abundance and species richness, however, the level of diversity was found to vary across each of the survey sites. A total of 775 individual specimens were collected, mounted, categorized into groups, and then labelled with details of where and when the specimen was collected (Figure 5). Mounted specimens were then kept in drawers at the CEI laboratory at the Department of Biology at the Royal University of Phnom Penh. A preliminary classification shows that 12 different orders of insects were identified during the survey. At KPWS, the species richness of 12 orders were found to be more abundant than others (Figure 6) including *Coleoptera* (beetles) (28%), *Hemiptera* (21%) (true bugs) and *Lepidoptera* (butterflies and moths) (15%)

Table 3. Insect orders present at each of the survey sites at *KPWS* and *Phnom Tnout Community Forest*

Sites / **Order**	**CA0094**	**CA0095**	**CA0096**	**CA0097**	**CA0098**	**CA0099**
Coleoptera	✓	✓	✓	✓	✓	✓
Dermaptera	✓				✓	✓
Diptera	✓	✓				✓
Hemiptera	✓	✓	✓	✓	✓	✓
Hymenoptera	✓	✓	✓	✓	✓	✓
Heteroptera			✓	✓	✓	✓
Lepidoptera	✓	✓			✓	
Mentodea	✓	✓	✓	✓	✓	✓
Odonata						✓
Orthoptera	✓	✓	✓	✓	✓	✓

Plasmatodea	✓	✓	✓	✓	✓	✓
Plecoptera	✓					✓

Table 4. A list of some morphospecies collected during the insect survey at *KPWS* and *Phnom Tnout Community Forest*.

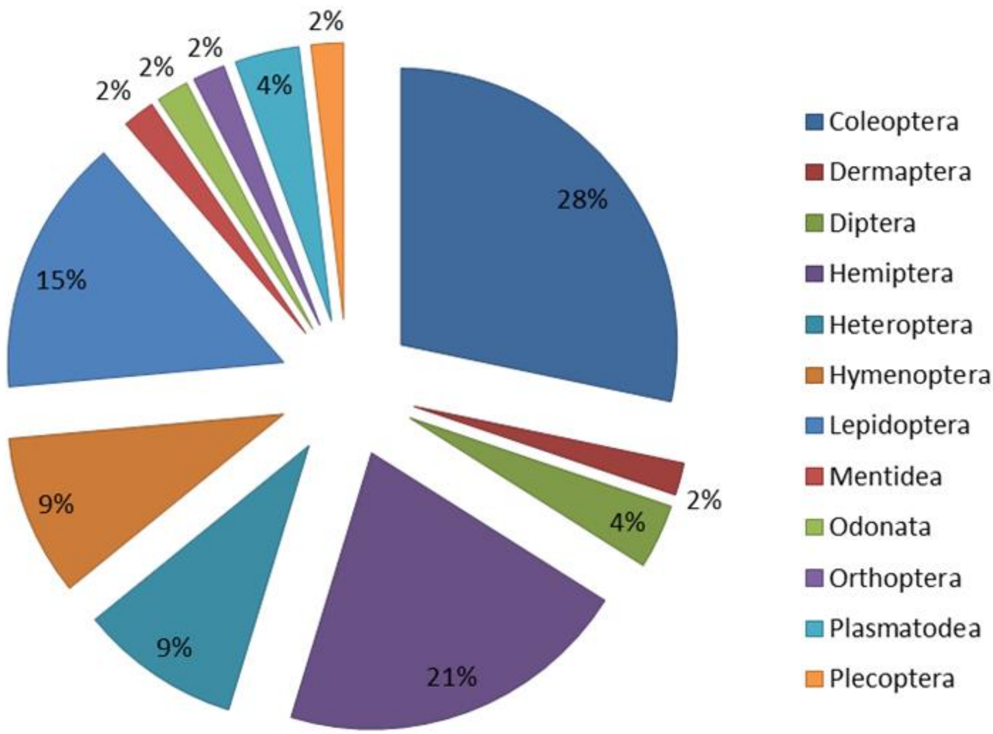
Orders	**Families**	**Species**
Hymenoptera	Apidae	*Apis sp*
Hymenoptera	Crabronidae	*Crabronidae sp*
Hymenoptera	Formicidae	*Formicidae sp*
Hymenoptera	Vespaidae	*Vespaidae vespa*
Hymenoptera	Pompilidae	*Pompilidae sp*
Orthoptera	Acrididae	*Acrididae sp*
Orthoptera	Gryllotalpidae	*Gryllotalpidae sp*
Orthoptera	Tettigoniidae	*Tettigoniidae sp*
Heteroptera	Gravidae	*Aradidae sp*
Heteroptera	Unknown	*Aphrophorida sp*
Heteroptera	Alydidae	*Alydidae sp*
Heteroptera	Pentatomidaae	*Pentatomidae sp*
Heteroptera	Berytidae	*Berytidae sp*
Hemiptera	Belostomatidae	*Belostoma sp*
Hemiptera	Coreidae	*Coreidae sp*
Hemiptera	Unknown	*Ledrinae sp*
Hemiptera	Tessaratomidae	*Tessaratomidae sp*
Hemiptera	Cicadellidae	*Cicadellidae sp*

Orders	**Families**	**Species**
Hemiptera	Cixiidae	*Cixiidae sp*
Hemiptera	Cicadidae	*Cicadidae sp*
Hemiptera	Reduviidae	*Reduvidae sp*
Hemiptera	Unknown	*Membracoidae sp*
Hemiptera	Lophopidae	*Lophopidae sp*
Hemiptera	Heterogastridae	*Heterogastridae sp*
Coleoptera	Cerambycidae	*Cerambycidae sp*
Coleoptera	Cicindelidae	*Cicindelidae sp*
Coleoptera	Curculionidae	*Curculionidae sp*
Coleoptera	Scirtidae	*Scirtidae sp*
Coleoptera	Unknown	*Unknown Coleoptera*
Coleoptera	Doliehopodidae	*Doliehopodidae sp*
Coleoptera	Disteniidae	*Disteniidae sp*
Coleoptera	Elateridae	*Elateridae sp*
Coleoptera	Hydrophilidae	*Hydrophilidae sp*
Coleoptera	Lygacidae	*Lygacidae sp*
Coleoptera	Scarabaeidae	*Melolonthinae sp*
Coleoptera	Meloidae	*Meloidae sp*
Coleoptera	Passalidae	*Passalidae sp*
Coleoptera	Scarabaeidae	*Helicopris bucephalus*

Orders	**Families**	**Species**
Coleoptera	Scarabaeidae	*Helicopris sp*
Diptera	Asilidae	*Asilidae sp*
Diptera	Unknown	*Unknown Diptera*
Dermaptera	Forficulidae	*Forficulidae sp*
Mentidea	Hymenopus	*Hymenopus sp*
Odonata	Odonata	*Odonata sp*
Phasmatodea	Phasmatodea	*Phasmatodea sp*
Phasmatodea	Toxoderidae	*Toxoderidae sp*
Plecoptera	Unknown	*Unknown Plecoptera*
Lepidoptera	Papilionidae	*Papilio memnon*
Lepidoptera	Pieridea	*Pieridea sp*
Lepidoptera	Nymphalidae	*Nymphalidae sp*
Lepidoptera	Nymphalidae	*Cethosia sp*
Lepidoptera	Nymphalidae	*Christmas sp*
Lepidoptera	Nymphalidae	*Ariadne sp*
Lepidoptera	Heterocera	*Heterocera sp*
Lepidoptera	Lycaenidae	*Lycaenidae sp*

The insect survey found 12 orders of insects at KPWS including *Coleoptera* (beetles), *Diptera* (flies), *Dermaptera* (earwigs), *Hemiptera* (true bugs), *Heteroptera* (true bugs), *Hymenoptera* (wasps, bees, and ants), *Lepidoptera* (butterflies and moths), *Mentidea* (mantis), *Odonata* (dragonflies and damselflies)*, Orthoptera* grasshoppers and crickets)*, Phasmatodea* (stick insects)*,* and *Plecoptera* (stoneflies), representing 53 families presented in Table 4. A total of 147 morphospecies were identified, with 7 of these still unidentified. These results are comparable to other morphological studies in Cambodia conducted by the CEI in other locations such as Kirirom and Phnom Kulen National Parks, and Keo Seima Wildlife Sanctuary.

Figure 6. Species abundance based on the number of families identified in each order.



In total, there were 53 insect families identified across the orders including *Coleoptera* (15 families), *Hemiptera* (11 families), *Lepidoptera* (8 families), Hymenoptera and *Heteroptera* (5 families of each), *Diptera* and *Phasmatodea* (2 families of each), as well as *Mentidea, Odonata, Orthoptera*, and *Dermaptera* (1 family or each). A total of 147 morphospecies were identified from the 755 specimens collected at KPWS. Eleven of these morphospecies were identified as new species not previously identified in Cambodia. These specimens included *Curculionidae* (true weevils) (2 species), *Pentatomidae* (stink bug) (1 species), *Elateridae* click beetle (1 species), *Membracidae* (treehopper) (1 species), *Ruduvidae* (assassin bug) (2 species), *Toxoderidae* (mantis) (1 species), *Meloidae* (blister beetle) (1 species), and *Heterocera* (moth) (2 species). The insect survey at Kulen Promtep found many morphospecies present across different habitat in significant abundance, as indicated by the species diversity of other wildlife species in the area. Kulen Promtep has much potential for future beyond the preliminary insect survey.

Discussion

Based on Shannon's diversity index (H) insect diversity in PKWS is highly abundant (H = 4.20694) and displays good evenness of species distribution (E_H = 0.85). These results are consistent across each of the major survey sites used for the study, with the sites within *KPWS* (CA0094-CA0098) showing similar results (H = 3.89733; E_H = 0.85) and to those at the second major survey site at *Phnom Tnout Community Forest* (CA0099). It is therefore assumed that the insect community in KPWS is diverse and abundant for all the specimens collected. However, the mixed habitat of dipterocarp and dry semi-evergreen forest in KPWS showed that some insect species were more dominant than others including Coleoptera (28%), Hemiptera (21%) and Lepidoptera (15%) orders. This reflects the results of a study on scarab beetles in a similar forest types in Northeastern Thailand (Sukapanpotharam, 1979), which shows that the results of this preliminary insect survey cannot be used to assume consistent species diversity over time. While the habitat of KPWS was shown to support abundant insect diversity and richness in May 2017, it is not feasible for one insect survey and diversity assessment to suggest that these ecosystems provide habitat to support insect diversity over different seasons or as changes to land use patterns occur associated with land use changes or the impacts of climate change. For example, a major threat to the habitat of insects at KPWS could be introduced by illegal logging activities (WCS Cambodia, 2017). There are also a range of other threats that could affect insect biodiversity. For example, if a large number of people settled in the forest and started to hunting food. These type of changes to species diversity, abundance, or evenness of insect population distribution would not be detected in a single preliminary survey (Hartmann et al., 2013).

Conclusion

KPWS and the surrounding forests of Phnom Tnout Community Forest comprise of diverse landscape including dipterocarp and dry semi-evergreen forest, as well other rainforested areas that support an abundant diversity of insect species. In total, the insect survey identified 147 morphospecies, including 7 species that have not yet been identified in Cambodia previously. However, these results were achieved over a relatively short preliminary survey. The inventory was also conducted in the dry season, where temperature reached between 36^{o}C and 40^{o}C, which is a not ideal method for obtaining a representative insect sample. The methodology used to conduct the survey, including specimen collection during the day and night, should be replicated at other times of the year to obtain more insight into the dynamics of insect communities in KPWS. Notwithstanding this, the specimens collected and their classification as a preliminary study of insect diversity at KPWS adds significant value to the body of knowledge of insect diversity in a protected forest ecosystem in Cambodia. However, the recorded taxa are unlikely to represent the total number of species present in KPWS. The six sampling sites used to conduct the insect survey were chosen with budget limitations and time constraints in mind. This restricted the scope of the study to random locations chosen on the basis of ease of access. Future insect surveys and species inventories in the region should consider a broader range of habitat types and include the participation of local and indigenous knowledge, as well as from international experts. This type of collaboration is likely to improve the outcomes of the survey and result in a more useful assessment of species richness and abundance.

Acknowledgments

We would like to thank for the Royal University of Phnom Penh for their financial support of this research through access to a University Research Grant (G2021117), especially the staff from the Research Office, who helped to facilitate this including Dr Sok Serey. Furthermore, we would like to acknowledge the research team of the Cambodian Entomology Initiative, Ms Keum Theary, Ms Keath Sophorn, Ms Rim Socheata, Mr Hout Cheysen, Mr Douerk Bros and other CEI members for assistance with field sampling equipment and the preparation and storage of insect specimens. We are grateful for the assistance of the Ministry of Environment and local rangers at KWSP in accessing the field survey sites during the fieldwork.

Corresponding Biography

PHAUK Sophany has worked as lecturer and researcher at the Department of Biology in the Faculty of Science at the Royal University of Phnom Penh since 2012. He studied the use of acoustics by bat species in Cambodia to assist with their identification for his MSc. His work is now focused on Cambodian insect diversity and its link to ecological processes to better understand scenarios such as climate change and agricultural pest control. He is also the manager and curator of the entomological collection at Cambodian Entomology Initiatives at the Department of Biology at the Royal University of Phnom Penh.

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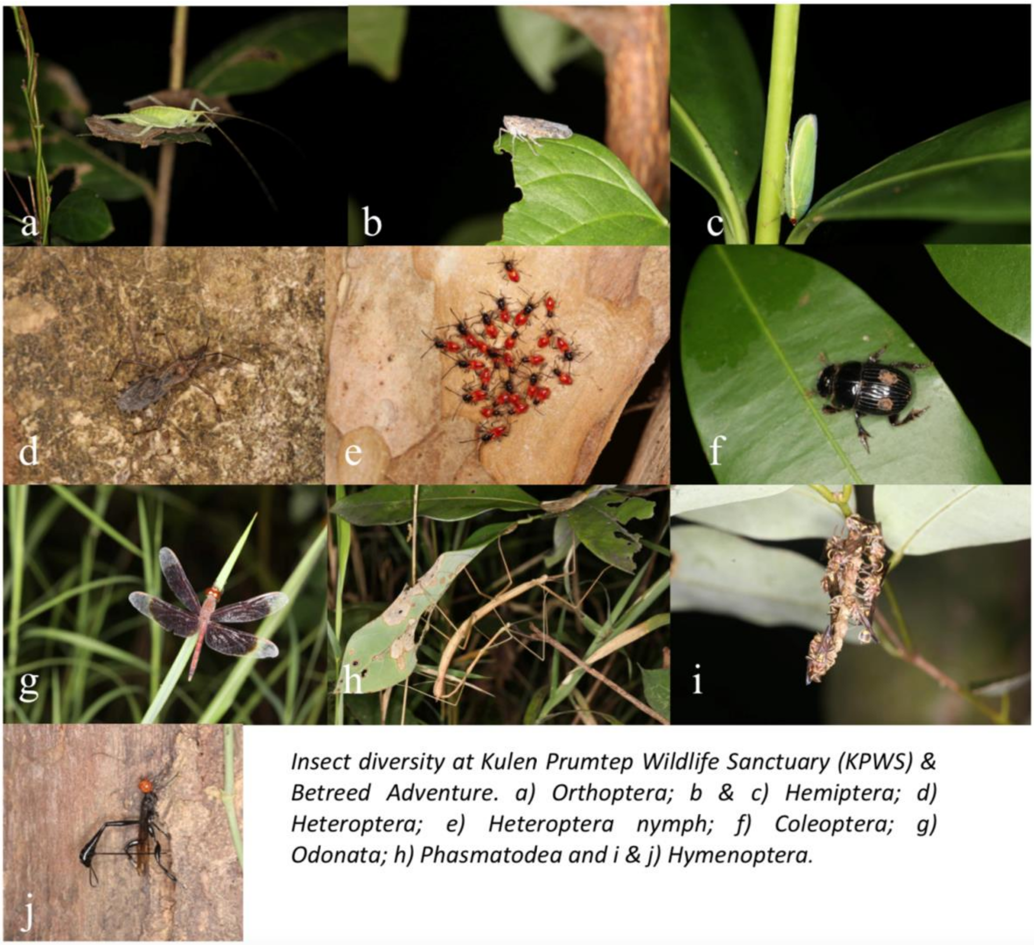
Appendix



Insect diversity at Kulen Prumtep Wildlife Sanctuary (KPWS) & Betreed Adventure. a) Orthoptera; b & c) Hemiptera; d) Heteroptera; e) Heteroptera nymph; f) Coleoptera; g) Odonata; h) Phasmatodea and i & j) Hymenoptera.

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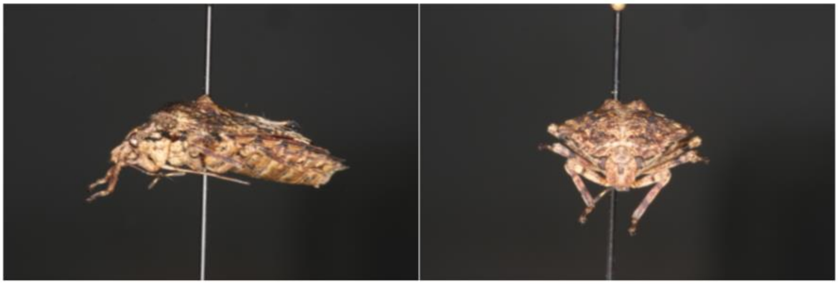
Morphospecies of some insect species collected

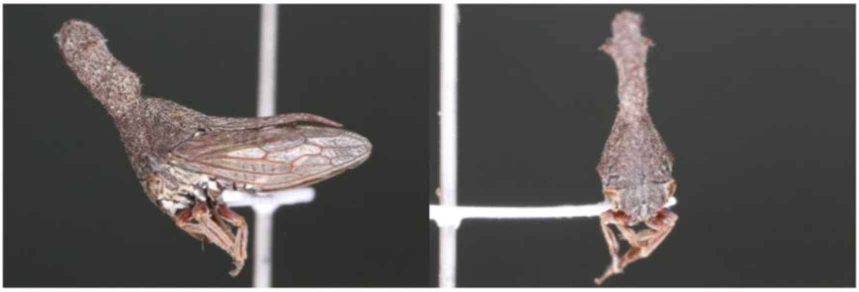


Coreinae sp1.

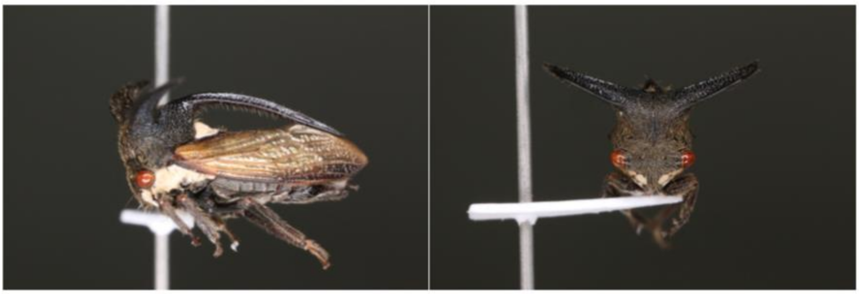
Coreinae sp2.

Reduviidae sp1.

Cicadellidae sp1.

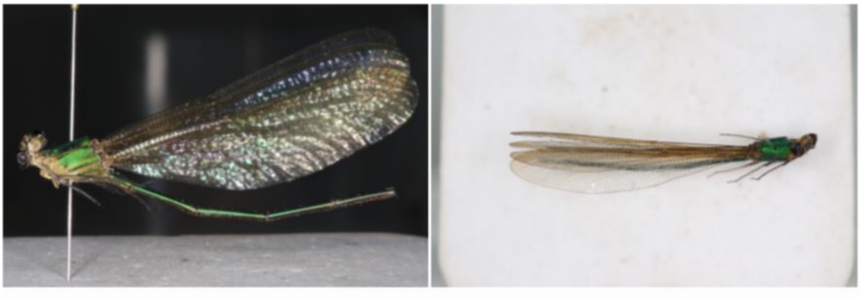


Membracidae sp1.



Membracidae sp2.

Dynastinae sp.



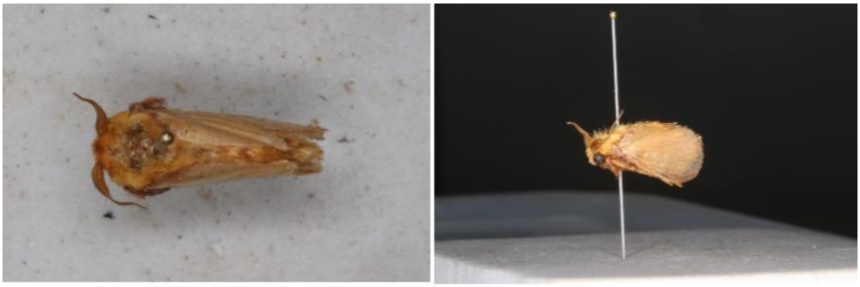
Odonata sp.

Curculionidae sp1.

Curculionidae sp2.

Elateridae sp1.

Meloidae sp1.



Heterocera sp1.

Heterocera sp2.

Vespoidae sp1.

Bothrogonia sp.

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Simulating future trends in stormwater runoff at a university campus related to climate and land use changes

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Stormwater management is essential for the management of sewerage and stormwater systems as insufficient drainage can result in flood damage and impact public health. During the planning of new infrastructure at Campus I of the Royal University of Phnom Penh, it was observed that a hydrological assessment had not yet been completed. Without such an assessment, climate change and poor land-use planning may result in more frequent flood events in the future. Thus, this study aims to quantify the potential impacts of changes to stormwater runoff related to climate change and an increase in the area of impervious surfaces on campus. PCSWMM modeling software was employed to simulate surface runoff volumes flowing to the catchment of the Building D pond. Three different scenarios for rainfall intensity (2, 5, and 10-year return period) and five scenarios for changes to impervious area (10%, 30%, 50%, 70% and 100%) were used in the simulation. A baseline was also established by analysing rainfall intensity, land use characteristics, and topography in the catchment area. Under present conditions the volume of the Building D pond is about 18,933 m^3 with a surface area of 6,173 m^2. The average permanent water volume of the pond is about 9,916 m^3, with a remaining storage capacity of 9,016 m^3. It is estimated that the pond will flood within one hour of intense rainfall (63.70 mm/h) under these conditions. The surface runoff volume for the Building D catchment was estimated for a range of scenarios. It was found that even under intense rainfall (63.70 mm/h); the pond would not flood if measures were implemented to reduce the impervious area on campus by 10%. This shows that preserving permeable surfaces in the

catchment is likely to reduce the frequency of flood events on campus over a range of climate change scenarios.
Keywords: stormwater, PCSWMM modeling software, climate change, surface runoff, Royal University of Phnom Penh

To cite this article: Sovann, C.P., Choi, M.D., Thou, S. & Yim, S. (2019) Simulating future trends in stormwater runoff at a university campus related to climate and land use changes. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 48–74

Introduction

Stormwater management is essential for mitigating the negative impacts caused by combined sewage-stormwater flood events due to insufficient drainage. These events often result in flood damage and poor public health outcomes (Barbosa et al., 2012). Stormwater runoff contains sediment, which often fills drainage channels, resulting in flooding (Livingston & McCarron, 1992; Chebbo et al., 1996; Liao et al., 2014; JICA, 2016, 2017). Effective stormwater management remains a challenge in both developed and developing countries (Goldenfum et al., 2007; Irvine, 2013; Smith, 2001; Chaosakul et al., 2013) such as in Malaysia (IRDA, 2011), Cambodia (Phyrun, 1996), China (Liao et al., 2014), and the United States (Parkinson & Mark, 2005; EPA, 2009).

The Royal University of Phnom Penh (RUPP) is one of the oldest and largest public universities in Cambodian and consists of three campuses. Campus I, the study area selected for this research is located about 5 km west of the center of Phnom Penh. The recent 'RUPP Vision' contained an Infrastructure Development Plan for 2014-2018 for Campus I (Royal University of Phnom Penh, 2018b). A number of new buildings were planned. Currently there are five ponds on campus that play a crucial role in stormwater management. These ponds store stormwater flows from rainfall events, as well as wastewater produced on-site. Without a detailed understanding of the hydrological response of each pond or the impact of an increased area of impervious surfaces, further infrastructure development has the potential to cause serious flooding and public health problems. This study aims to assess the potential impacts of increased surface water runoff related to an increase in the impervious area within the catchment of the Building D pond at RUPP and more intense rainfall due to climate change.

Study area and methodology

This study takes place at Campus I of the Royal University of Phnom Penh, which covers an area of approximately 20 ha. There are five main ponds at the campus, with a total area of approximately 3 hectares. They include the: [1] 'Big pond' in front of Main Building (1.8 ha), [2] 'IFL back pond' (0.30 ha), [3] 'Building D pond' (0.41 ha), [4] 'IFL front pond' near the car parking lot (0.21 ha), and [5] 'CJCC pond' (0.16 ha). The Building D pond is arguably the most polluted and flood-prone. It is the final retention pond for wastewater flows and also regulates stormwater flows before they are pumped to an external open canal.

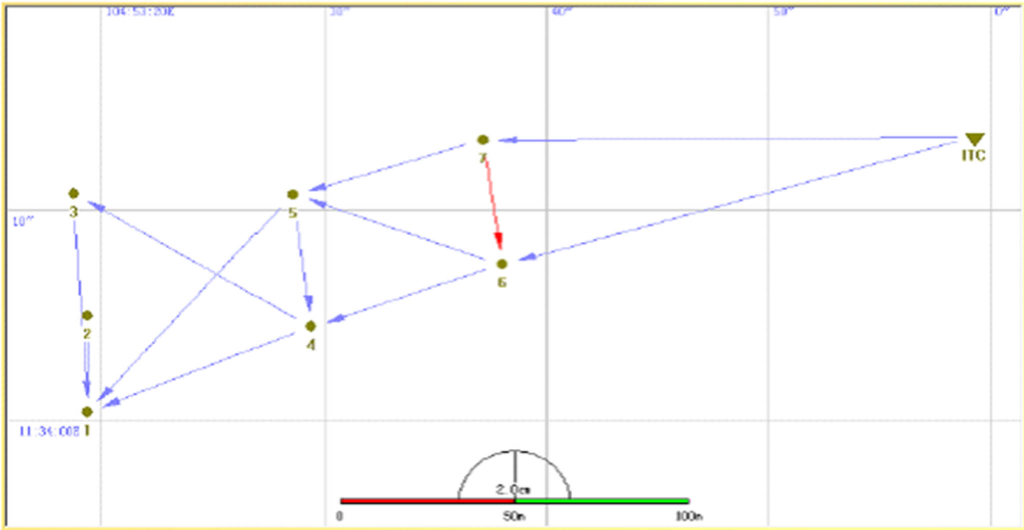
Rainfall

A Davis Vantage Pro2 Plus weather station purchased with financial support from the University of Manchester was installed on the roof of the Cambodia-Korea Cooperation Center (CKCC) to record rainfall and other weather data at 1-minute intervals. This data was then converted to 5-minute intervals for use in the PCSWMM modeling software to determine a baseline value for stormwater runoff for comparison with future scenarios for rainfall intensity linked to the impacts of climate change.

Bathymetric and topographic survey

Seven static reference points were identified for use as topographical benchmarks at RUPP Campus I in August 2017. These points were determined using three sets of CamNav T300 GNSS receivers (Horizontal: 2.5mm + 0.5ppm RMS & Vertical: 5mm + 0.5ppm, RMS) to triangulate networked static points with a known reference point at the Institute of Technology, Cambodia (ITC) as a benchmark. For this survey, a five-second interval was used for measuring the static points, with the baseline approximately 700 m away from reference point. In total, six sections were surveyed, maintaining the static survey as part of a triangulated loop involving at least one of the three receivers remaining in place (Figure 1). For example, Section 1 was surveyed as part of a triangulation of the data from ITC, and Points #7 and #6. Then, one receiver was moved to point #5 and triangulated with data from Points #7 and #6 for Section 2. Successive sections were triangulated using the same procedure of moving most distant station to a new control point for Sections 3, 4, 5 & 6, as shown in Figure 1. Horizontal (X, Y) data were referenced to a national coordinate system benchmark (UTM WGS84, Zone 48N) and height data (Z) was transformed from ellipsoidal height to orthometric height (geoid model EGM2008). These static data points were adjusted using Compass Solution software (Version 1.7.0 Copyright 2014-2020) to ensure centimeter scale accuracy. As the RMSE was not acceptable for all baseline points, this software was also used to further process the data by making adjustments to provide millimeter accuracy. The coordinates for each of the seven benchmarks was then finalized.

Figure 1. Triangulation loops for the three GNSS receivers used to determine a statistical baseline.



In total, 401 real-time-kinetic (RTK) points were collected twice, with 69 points collected in August 2017 and 332 points collected in February 2018. Sixty-six of these points were collected at the ground level of a building. To survey most of the RTK points, one T300 receiver was used as a base station at Point #4 (near the flag pole), while the other two receivers were used as rovers to collect 3D RTK data (x, y, z). These data points were collected for five seconds at each point to minimize errors to less than 15mm. The 66 RTK points collected from the ground level of the buildings within the Building D pond catchment area were used to determine an average ground floor elevation for each building. Using an assumption that the ground floor elevation of each building was completely level; an extra 836 ground elevation points were generated. An extra 438 points were also collected using a CST Berger Auto

Level (SAI 24X) between the 1st and the 10th of January 2017 to better understand the topography of the Building D catchment area. This auto level survey was conducted using 41 straight-line transects at 20-meter intervals.

A total of 313 of bathymetric survey points for the Building D pond were collected between January 2017 and February 2018. The bathymetric survey was conducted manually using a pole to measure the depth of the pond along 17 transect lines from north to south and 20 transect lines from west to east. Assuming a high slope change from the bank to an elevation of 10 m, a short transect line at 2.5 m interval was used for this survey, while other transect lines were recorded at 5 m intervals. The bathymetric survey was conducted over a time period where the water level in the water level in the pond is likely to have changed. Thus, a global water level (WL16U) was installed between the 8th of January and the 14th of February, 2018 (X: 487912.222, Y: 1278880.034 and Z: 7.62) to obtain water depth data at 5-minute intervals. These data were used to adjust the bathymetric data to reduce errors associated with changes in the depth of the pond. The ground elevation of the pond was then determined using the adjusted bathymetric, comparing water depth with ground elevation data with reference to a benchmark (X: 488171.743 and Y: 1278776.169) collected with the CamNav T300 GNSS receivers on the 11th of August 2017.

To surface topography of the Building D pond catchment was then further analyzed by combining the 313 points collected from the bathymetric survey, 417 static and RTK points, 438 auto-level points, and the 836 ground floor elevation points. After cleaning this dataset of errors and accounting missing values, a dataset of 1926 survey points remained for use in the simulation. However, only the 1820 data points from Building D and within 30 m of the Building D sub-catchment were used for the topographic interpolation, with 90% of these points used for training the data and 10% used for testing the data. Two inverse distance weighted (IDW) interpolations were then used in ArcGIS (Ver. 10.5) to calculate the storage capacity of the Building D pond, the average slope of Building D, and the STEM building sub-catchment size.

Catchment delineation and impervious area

The Campus I catchment, Building D pond sub-catchment, and STEM building sub-catchment were delineated using Google Earth high-resolution satellite imagery downloaded on the 15th of January, 2018. A time series percentage change from pervious and impervious area in each catchment and sub-catchment between 2000 and 2017 was also generated based on this imagery. However, only recent pervious area could be analyzed by digitizing the high-resolution satellite imagery as the present condition of pervious and impervious area needed to be used as an input for the PCSWMM model.

Drainage and sewage system mapping

The drainage system to the east of the Building D pond includes nodes, conduits, and outfalls. These were also mapped in relation to the observed data in terms of flow direction, the size of drainage system, the invert ground level, the maximum level, and sediment height. This data for the sewerage and drainage system data connected to the Building D pond catchment was collected between the 25th of March and the 25th of April, 2018. A staff member of the campus was interviewed to draft a preliminary map of the system and determine the number of pumps and their direction of flow on a seasonal basis. The first draft of map was verified with the staff member ahead of on-site data collection, measuring pipe nodes, diameters, heights and sediment heights using a crowbar, scaffolding planks, and measuring tape. The type of pipes installed was also recorded. On the 29th of March and the 3rd of April, 2018, two GNSS Reach RS receivers were used to conduct static and RTK surveys to determine the coordinates and elevation of each node. A known static point near the RUPP flagpole (X: 488171.743, Y: 1278776.169, Z: 11.4195) was used as a reference point for the survey. The RTK data was then compiled in Microsoft Excel prior to being transferred to ArcGIS software (version 10.5) to map the drainage system.

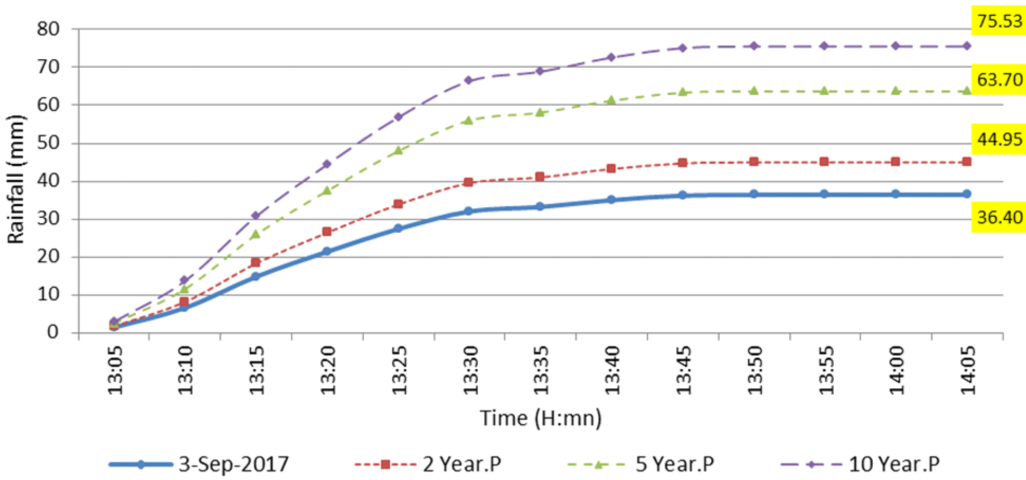
Flow rate and water level

There was only one flow meter available for the study; however, there are seven outfalls flowing to the Building D pond. Thus, only the flow from one outfall could be selected for long-term flow monitoring. The STEM building outfall (X: 487960.429729, Y: 1278926.11455, Z: 6.0951, pipe's diameter = 0.3 m) was selected as the most appropriate outfall and the flow, in terms of water level and flow velocity was recorded at 5-minute intervals between the 22nd of August, 2017 and the 22nd of January, 2018. The entire dataset was then cleaned and analyzed using descriptive statistics to determine an appropriate time period for a rainfall-runoff simulation informed by a more detailed understanding of dry flow patterns.

Surface runoff simulation

The PCSWMM model, developed by EPA SWMM, was used to estimate surface runoff for a one-hour period of rainfall from the STEM building and the Building D pond sub-catchment (Figure 2).

Figure 2. 5-minute rainfall intensity for selected rainfall patterns calculated for a 2-year, 5-year, and 10-year return period.



The model applying the Green-Ampt infiltration method to conduct an analysis using Manning's equation to estimate the maximum depression storage, assuming N-impervious and N-pervious were 0.011 and 0.1, respectively. To examine the change in surface runoff for each of the sub-catchments, two main types of scenarios were considered. These included changes to the impervious area (representing infrastructure development) and rainfall intensity changes (representing predicted climate change impacts). For infrastructure development, five alternative scenarios were considered including an increase in impervious areas of 10%, 30%, 50%, 70% and 100 % of the STEM building sub-catchment and Building D pond sub-catchment. For the predicted climate change impacts, it was assumed that rainfall intensity will increase in the future. Thus, three scenarios were considered including a 2, 5 and 10-years return period for hourly rainfall in Phnom Penh based on a previous study (JICA, 1999)

Findings and Results

Results from the topographical survey

Table 1 presents the elevation points of several buildings at RUPP including, the CKCC Building, Building D, Building B, the STEM building, study office, Building A, the swimming pool and library. The points were measured using a topographic method to determine the proportion of wastewater that would flow to the Building D catchment using a reference point of above mean sea level (AMSL). The study office had the highest elevation point with an average of 11.59638 m across 13 measurement points. Four other buildings had a mean elevation point only slightly lower than the study office, including the swimming pool (11.561 m), Building A (11.47143 m), Building B (11.4174 m) and the CKCC Building (11.162 m). Building D had the lowest mean elevation (8.295 m), while the STEM Building had a mean elevation of 8.98375 m and 9.112 m, respectively. Each of these buildings is at least 8 m above AMSL and the wastewater produced by each building is pumped to Building D catchment. The area of the pond, excluding the island in the middle, is approximately 6173 m^2 and the potential water storage volume is 18932.29 m^3, calculated on the basis of the plain height being 8 m.

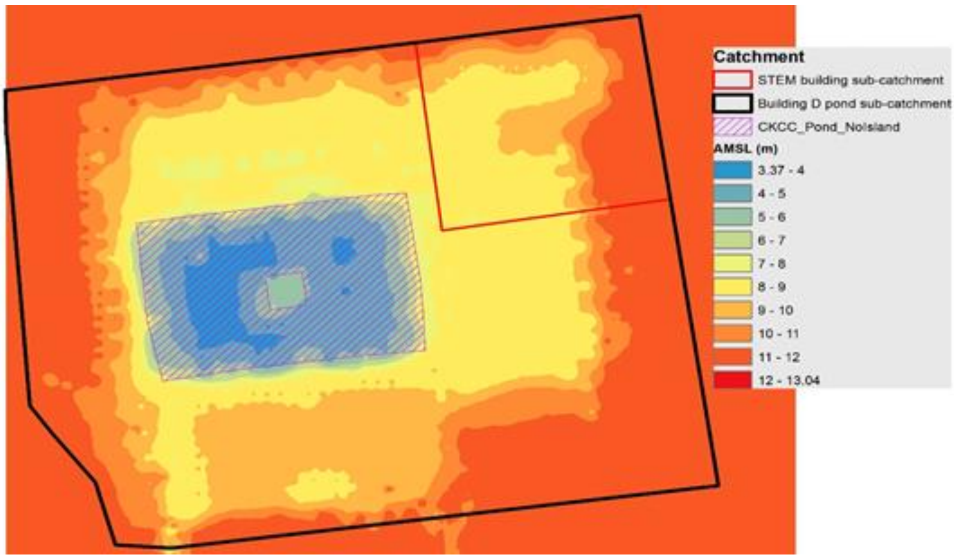
From the data collected from the auto level installed in the Building D pond (X: 487911.493, Y: 1278879.788, Z: 5.326) between the 8th January to the 14th February, 2018, it was observed that the average water level in the pond was 1.13 meters, which corresponds to 6.456 m AMSL (n = 12086, std. = 0.074). This suggests that most of the time, there is 9,916 m^3 of water stored in the pond, with a surface area of 5,631.96 m^2. Thus, there is a capacity for a further 9,016.07 m^3 of stormwater and wastewater to be stored in a flood event (Figure 3).

Table 2. Ground level elevation of each building at Campus I.

Building	Points	Average	Std. Error	Minimum	Maximum
Building CKCC	4	11.162	0.185872	10.841	11.288
Building D	4	8.295	0.089808	8.201	8.394
Building B	10	11.4174	0.038487	11.366	11.483
STEM building	4	8.98375	0.096893	8.87	9.138
Study office	13	11.59638	0.131215	11.301	11.751
Building A	14	11.47143	0.074564	11.32	11.617
Swimming pool	5	11.561	0.205342	11.32	11.943
Library	12	9.112	1.301047	7.717	11.575

The impervious area of the RUPP campus, within the Building D pond and STEM Building sub-catchments was measured in hectares over the period between 2000 and 2017. For the first five years, the impervious zone in Building D Pond sub-catchment was unchanged at 19.73% of the total area (0.87 ha out of 4.39 ha). However, in 2007 the impervious area increased to 1.14 ha, and again in 2012 to 2.26 hectares or 51.38% of the total area. By 2017, the impervious area had reached 2.64 ha or approximately 60% of the total area. The impervious area of the STEM building catchment area increased from about one-fifth to one-third (0.18 of 0.62 ha) between 2000 and 2010 and then remained stable until 2015. The impervious area again increased to close to 50% (0.29 hectares) in 2016 and one-year later covered two-thirds of the total area. This growth is consistent with the overall increase in impervious surfaces throughout Campus I at RUPP. The impervious surface of the campus doubled in size from 3.32 ha to 6.63 ha out of a total of 20.38 ha between 2000 and 2008. This area again increased to 7.46 ha in 2010, and 9.54 ha in 2017 and now covers approximately half of the campus (Figure 4).

Figure 3. A map showing the boundaries of the STEM building and the Building D pond sub-catchments with elevation data.



Storm and wastewater infrastructure and level measurement

A preliminary study of the drainage infrastructure at RUPP revealed a complex array or junctions, pumps stations, outfalls, wastewater and septic tanks, as part of the drainage and sewage network (Figure 5). The system is used to drain wastewater and stormwater from the campus and comprises 94 different junctions (55 for sewerage and 39 for drainage), 3 pump stations, 17 outfalls, 5 wastewater tanks, and 8 septic tanks.

The raw flow and water level data taken in 5-minute interval for the STEM building outfall suggest that a flood event correlates to a water level above 300 mm and dry outfall flow conditions correlates to water level below

100 mm. Thus, this dataset was cleaned to remove any values outside of these limits for the simulation. The clean data comprised 24,073 data points with a maximum and minimum value of 124.092 mm and 0 mm, respectively, with a standard deviation of 16.2859 mm. The median value was 2.6771 mm, while the average was 12.4657 ± 0.1049mm at a 95% confidence interval (CI (95%)) of 0.2057.

Figure 4. Change to the impervious area of Campus I between 2000 and 2017.

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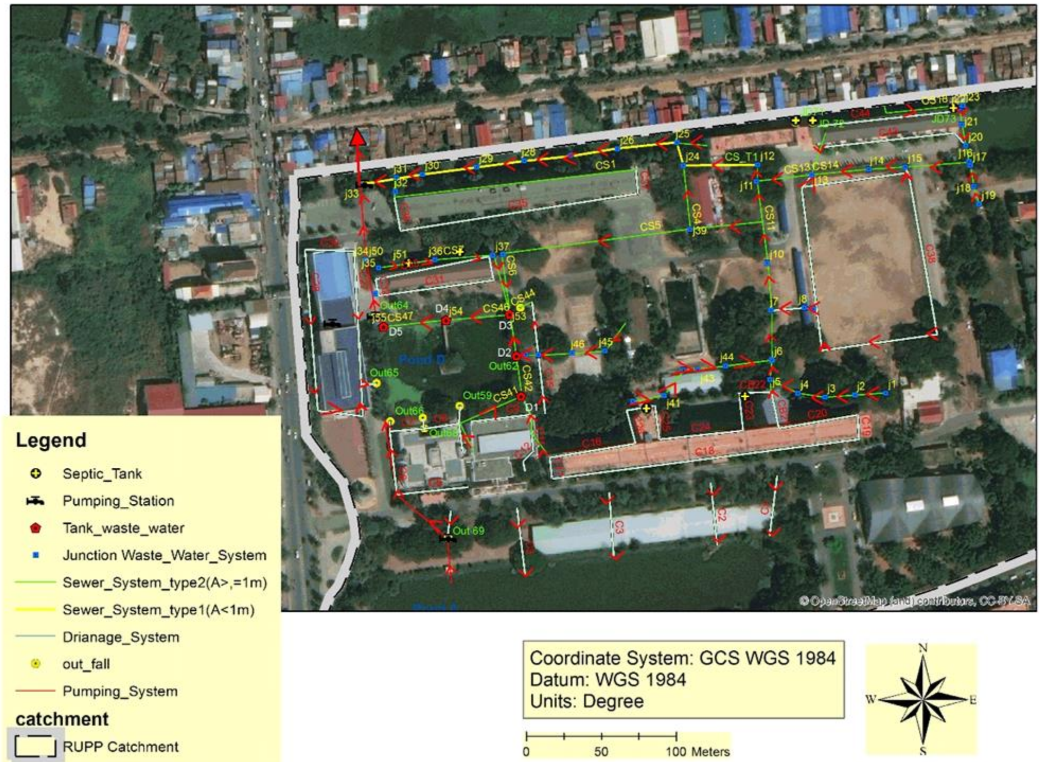
Figure 5. Map of the drainage and sewer system at RUPP Campus I.



The water flow level from the Building D outfall, taken at 5-minute intervals for the week between the 28th of October and the 30th of November, 2017 were then analyzed further (Figure 6). This week was considered as ideal as there had been no rain for 24 hours before the sampling and the outfall was not flooded during this period. Either scenario may have otherwise affected the analysis of the dry flow.

A peak water level of 40.7268 mm and a trough of 0 mm was recorded during this week, with a mean value of 4.8357 ± 0.1881 and a standard deviation of 8.1245 mm (n = 1865, CI (95%) = 0.3689). Between the Monday and Friday of this week, when both the peak and trough were reached, the mean value of the water value was lower at 4.6464m ± 0.3568 with a standard deviation of 8.5641 mm (n = 4.6464, CI (95%) = 0.7008). On the weekend, the peak was reduced to 39.1971 mm but the mean value increased to 5.4895 mm ± 0.326, with a standard deviation of 7.8337 mm (n = 576, CI (95%) = 0.6410).

Figure 6. Time series data for rainfall events and the outfall water level from the STEM building sub-catchment between the 25th of August 2017 and the 18th of January, 2018 recorded at 5-minute intervals.

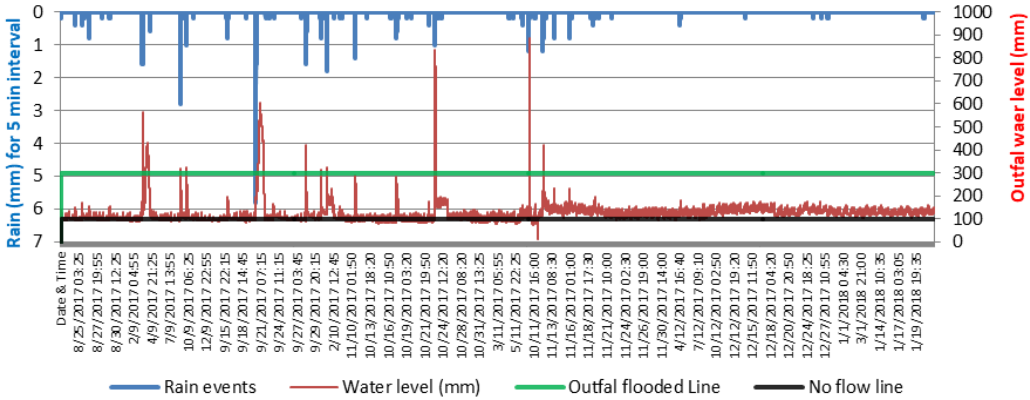
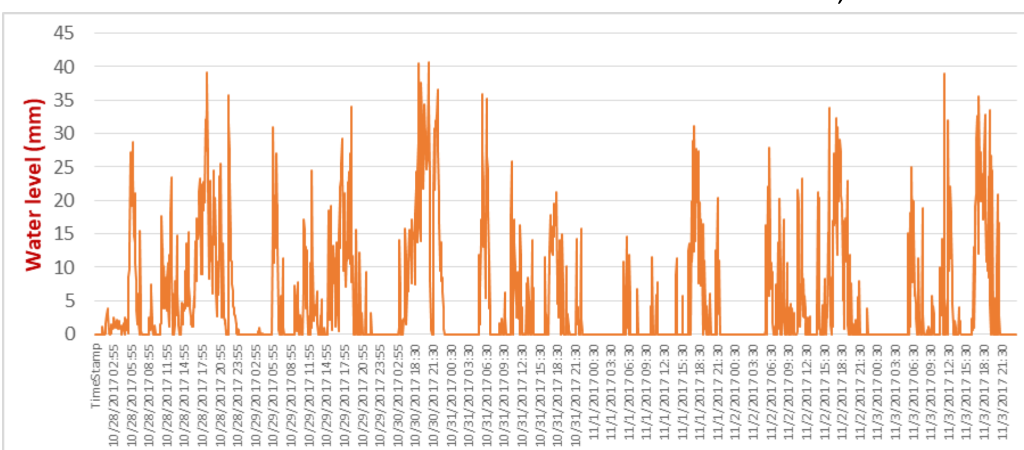


Figure 7: Dry flow water levels at 5-minute intervals at the STEM outfall for the week between the 28th of October and the 3rd of November, 2017.



Runoff calculation

The results from the simulation of the STEM Building sub-catchment show that an increase in impervious area has little impact of total runoff height. At present, the impervious area is two-thirds of the total area and the runoff level in the simulation is 35.93mm, correlating with a run-off volume of 240 m^3. If the rainfall intensity remained the same and the impervious area was increased by 100%, the simulated height would only increase to 36.59 mm (250 m^3). If it were reduced by 10%, it would decline to 33.06 mm (220 m^3). In the case of the STEM building catchment, the three scenarios for increased rainfall intensity as a result of climate change would a have a more significant impact. For example, for a 2-year, 5-year, and 10-year return period for rainfall, the runoff level would increase to 44.52 mm (300 m^3), 63.36 mm (420 m^3), and 75.24 mm (500 m^3), respectively. For an increase in impervious area of 100%, this would be 45.2 mm (300 m^3), 64.07 mm (430 m^3), and 75.96 mm (510 m^3), respectively. For a scenario, where measures were taken to reduce the impervious area by 10%, the runoff would slightly decline to 41.56 mm (280 m^3), 60.19 mm (400 m^3), and 71.98 mm (480 m^3), respectively.

Figure 8. The result of estimated surface runoff level at STEM building sub-catchment responding to different scenario of changing in [1] percentage of impervious areas and [2] rainfall intensity.

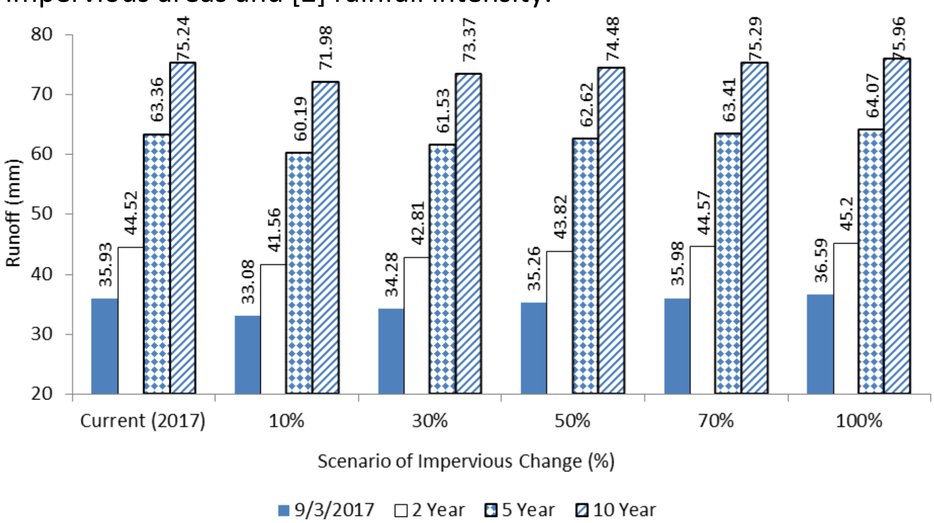


Figure 9. The results of estimated runoff levels at Building D pond sub-catchment responding to different scenarios for [1] the percentage of impervious areas, and [2] rainfall intensity.

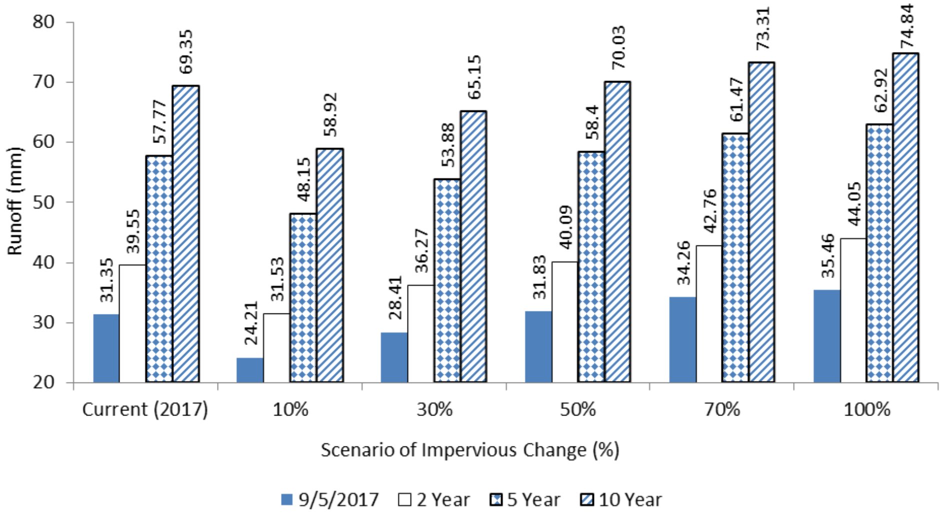
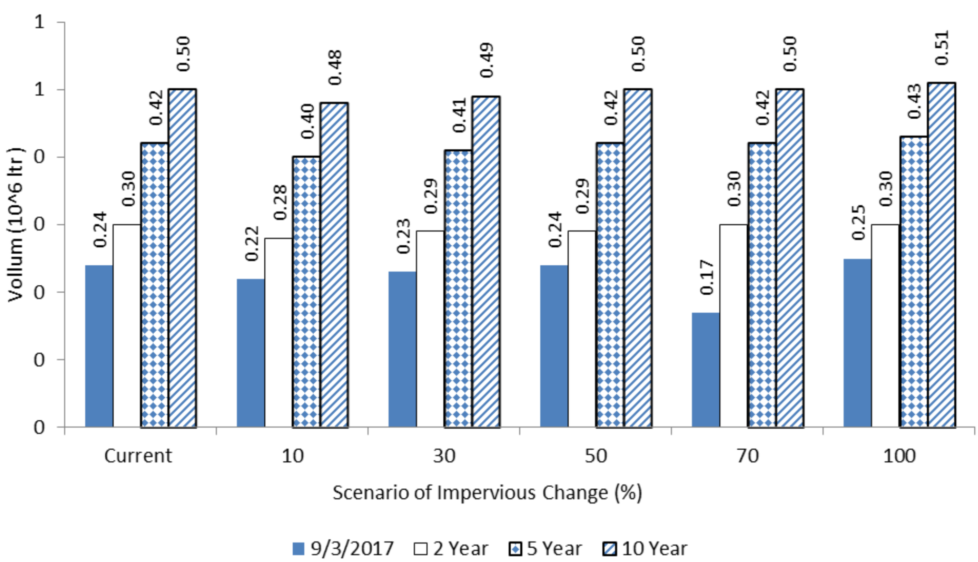


Figure 10. The result of estimated surface runoff volume level at the STEM building sub-catchment responding to different scenarios for [1] the percentage of impervious areas, and [2] rainfall intensity.



For the CKCC Pond, the simulation suggests that each scenario tested would have a more significant effect on the sub-catchment. The level and volume of the run-off based on a simulation of baseline conditions suggests a flow of 31.35 mm (1,520 m^3). Both a 100% increase in the impervious area and a 10% decrease in the impervious area would have a pronounced effect in the sub-catchment. For example, under these scenarios, the runoff would be 35.46 mm (1,590 m^3) and 24.41mm (1,280 m^3), respectively. In addition, increased rainfall intensity would also have a very significant impact on runoff. For example, under the climate change scenarios of a 2-year, 5-year and 10-year rainfall return scenario applied to the baseline, the run-off level and volume would be 39.55 mm (1,900 m^3), 57.77 mm (2,720 m^3) and 69.35 mm (3,240 m^3), respectively. If the impervious surface in the sub-catchment expanded by 100%, this would correlate to a runoff of 44.05 mm (1,970 m^3), 62.92 mm (2,800 m^3), and 74.84 mm (3,320 m^3), respectively. In the case of the 10% reduction in impervious area based on changes to infrastructure development, lower runoff values of 31.53 mm (1,630 m^3), 48.15 mm (2,420 m^3) and 58.92 mm (2,920 m^3) were simulated.

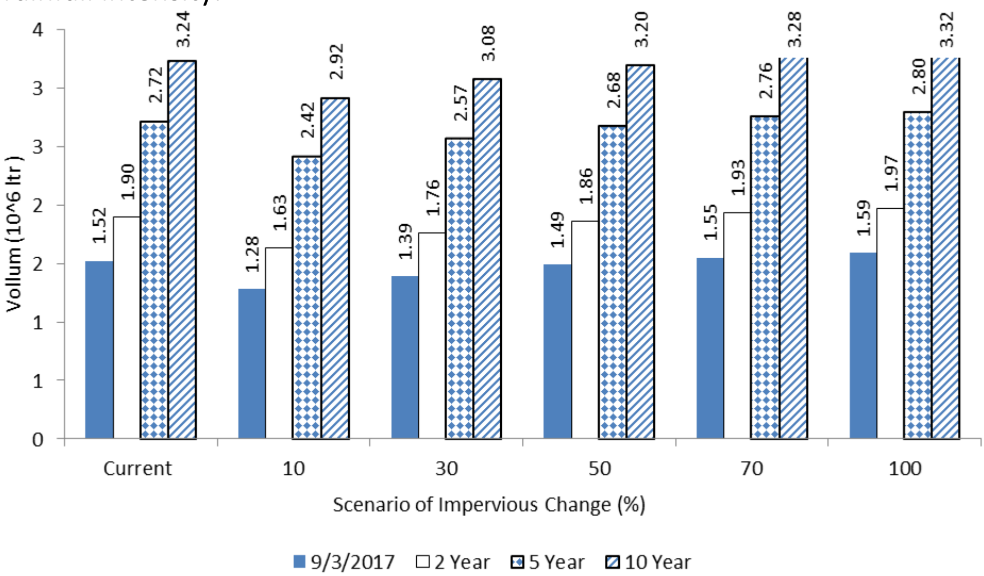
Runoff volume and the Building D pond stormwater flood analysis

In STEM Building sub-catchment simulation, there was not much difference in the level of surface runoff even with a significant increase in impervious area. This is because the sub-catchment is quite small (0.62 ha) and as discussed in a previous section contributes a much smaller run-off volume compared with the CKCC building sub-catchment for all rainfall intensity scenarios. However, the Building D pond sub-catchment currently carries a much more significant run-off volume (1,520 m3) as the area is comparatively quite large (20.38 ha). In this case, changes to both the impervious area in the sub-catchment and rainfall intensity result in a more significant change to run-off volume. This means that changes such as putting in lower the amount of impervious area by 10% in the second sub-catchment will have a much more pronounced effect on flooding.

To analyze the potential for a flood event to affect the Building D pond caused by stormwater flows, several scenarios of rainfall intensity, changes to impervious area in the catchment, and rainfall duration were considered. It was found that if all the stormwater collected at Campus I is directly discharged to the Building D pond, then the pond will flood after one-hour of rain at an intensity of 63.70 mm/h (5-year return period) as surface runoff volume in this event would be 11,740 m^3; while the water storage capacity of the pond is only 9,016 m^3. However, in another scenario, where the current impervious area (60.03%) is applied and only the stormwater from the Building D pond sub-catchment discharges stormwater runoff into the Building D pond, a rainfall intensity of 218.4 mm/day would be required to flood the pond.

Furthermore, if hypothetically, the pervious area of the catchment was increased by a further 50%, this level of rainfall intensity would not cause the pond to flood. This highlights the minimal impact of stormwater collected within the STEM building sub-catchment on the Building D pond due to its small area compared to the storage capacity of the pond. For example, even if the runoff volume from the STEM building sub-catchment area was based on a totally impervious area and a maximum rainfall intensity of 75.53 mm/h (10-year return period) experience over 10 hours, this would only still only account for a 5,100 m^3 run-off volume. This analysis assumes that [1] the pumps in the Building D pond are not operated, [2] there is no dry inflow into the pond, [3] water evaporation and groundwater infiltration into the pond are not considered, and [4] groundwater storage capacity is not included in the simulation.

Figure 11. The simulated runoff volume from the Building D pond sub-catchment under varying scenarios [1] percentage of impervious area, and [2] rainfall intensity.



Conclusion

The topography of Campus I at RUPP was studied based on 1,820 elevation points collected as part of a hydrological assessment. This data showed that the elevation of Campus I ranged from 3.3696 to 13.1761 AMSL. An IDW interpolation of the elevation data based on pair-test training of a small area ground with an independent dataset showed no statistically significant difference between the mean values of the two datasets. The Building D pond sub-catchment was estimated to have an average elevation of 9.0510 AMSL (SD = 2.1536) with a low elevation of 3.3713 AMSL. This sub-catchment was estimated to have an average slope of 10.1317 % (SD =

12.1679). The average of elevation and slope of the STEM building sub-catchment was 9.7707 m (SD = 1.2302) and 8.2155% (SD = 10.1699), respectively.

The topography of the Building D pond was used to estimate a pond volume of 18932.29 m^3 and a pond area of 6,173 square m^2. The mean permanent volume of water in the pond was estimated to be 9916.22 m^3. Thus, an extra combined stormwater and wastewater load of up to 9016.07 m^3 could be stored before the occurrence of a flood event. At RUPP there has been a trend at Campus I for the proportion of impervious areas to gradually increase from 16.31% to 46.80% between the 2000 and 2017. In 2017, the percentage of impervious area in the Building D pond catchment area was 60.03%, while STEM building sub-catchment was 68.44%.

The stormwater and wastewater infrastructure at Campus I is complex with 94 different sewerage and drainage junctions, 3 pump stations, 17 outfalls, 5 wastewater tanks and 8 septic tanks and some uncertainty about flow direction and the capacity of groundwater storage. Future studies should focus on clarifying these details to improve simulation results. Notwithstanding this, the simulation results showed a positive correlation between the surface runoff volume, an increasing impervious area in the sub-catchment, as well as for rainfall intensity. The total runoff volume at RUPP was calculated to be 36.40 mm/h, which with an impervious area of 46.8% or a total runoff volume of 6370 cubic m^3. This figure increases to 15220 m^3 if a simulation is performed with a rainfall intensity of 75.53 mm/h and impervious area of 100%.

The aim of the hydrological assessment was to analyze the potential of flood events in the Building D pond from stormwater flows. It was assessed that the pond is likely to experience more flood events in the future due to pressure from an increasing area of impervious surfaces and increasing rainfall intensity. Under present conditions, the pond is likely flood within an hour, if all the stormwater in the catchment was directly discharged into to the pond with a rainfall intensity of 63.70 mm/h (5-year return period). However, this same amount of rainfall would not flood the pond if the impervious area on campus is reduced by 10%. The study has shown that the preservation of pervious area in the catchment is likely less flood frequency in the Building D pond under the pressure of climate change. Based on this study, we conclude that the preservation of pervious areas in the catchment is likely to reduce the occurrence of flood events in the Building D pond in the event of increased rainfall intensity as a result of climate change. The pervious areas of the campus should be increased to increase the water storage capacity of the catchment and reduce run-off volumes.

Acknowledgments

This research was mainly supported by a University Research Grant from the Royal University of Phnom Penh. Scientific equipment for this project was made available with the supported of the International Fund for Scientists (IFS), Sweden, and the University of Manchester, United Kingdom. We acknowledge the assistance of undergraduate students from the Department of Environment and the Department of Geography and Land Management at RUPP in data collection. This paper does not necessarily reflect the views of any funder or supporter of the project acknowledged here.

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Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Prevalence and concentration of *Escherichia coli* and *Salmonella* species in fresh vegetables collected from different types of markets in Phnom Penh

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Freshly-eaten vegetables have become more popular in Cambodian diet. However, these vegetables are also one of the main sources of infection from pathogenic microorganisms if they become contaminated. Outbreaks of foodborne diseases caused by fresh fruits and vegetables have been increasingly reported, raising concerns regarding their safety. Therefore, it is very important to conduct an inquiry into the contamination of fresh vegetables by *Escherichia coli* and *Salmonella* spp. This study investigates the presence and concentration of *E. coli,* total coliforms, and *Salmonella* in samples of lettuce, saw-leaf herb, and cucumber, collected from different types of market in Phnom Penh. The spread-plate technique was used to detect the number of bacteria in each sample. The results indicate that the incidence of bacterial contamination in fresh vegetables, particularly lettuce and saw-leaf herbs, was higher in the wholesale markets than the other three types of markets. The concentration of *E. coli* in each of the samples ranged between 2 x 10^3 and 7 x 10^5 CFUs/g from the retail markets. The concentration of total coliforms was also found to be quite high. *Salmonella* was present in almost all leafy vegetable samples but in very few in cucumber samples. Bacteria reduction from the samples by thorough washing under flowing tap water was effective in most cases.

Keywords: fresh vegetables, *Escherichia coli*, total coliforms, *Salmonella*, pathogen removal

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

To cite this article: Phoeurk, C., Tieng, S., Tan, S., Moeung, S., Cheu, S., Chean,P.R.C., Hay V., Say, C., Lim, L. & Kann, L. (2019) Prevalence and concentration of *Escherichia coli* and *Salmonella* species in fresh vegetables collected from different types of markets in Phnom Penh. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 75–95.

Introduction

There are many kinds of vegetables people prefer eating raw believing they can obtain more vitamins, dietary fiber and protein from their diet (Slavin & Lloyd, 2012; Chau et al., 2014). These freshly eaten vegetables include lettuce, cucumber, water spinach, carrot, tomato, saw-leaf herb. All have become more popular recently in the Cambodian diet. However, these vegetables are also considered a major source of infection by pathogenic microorganisms via agents such as fungi, bacteria, viruses, and parasites (WHO, 2008). Reports of foodborne disease outbreaks related to fresh fruits and vegetables have been increasing in number, raising concerns about the safety of these products (WHO, 2008; Berger et al., 2010; Dolye & Erickson, 2008; Heaton & Jones, 2008; Lynch *et* al., 2009).

Bacterial pathogens are considered to be the most typical agent causing foodborne diseases, followed by viruses (Painter et al., 2013). Food-borne pathogens have a serious impact on public health outcomes. For example, in the United States alone, about 14 million incidents of food-related illness occurred in one year (Mead et al., 1999). Between 1996 and 2008, most foodborne disease outbreaks were linked to leafy green vegetables. *Escherichia coli* O157: H7, a Shiga toxin-producing serotype of the bacterial species *E. coli* and causing hemorrhagic diarrhea and kidney failure, and *Salmonella,* a bacterial species causing Salmonellosis and/or typhoid fever, were involved in up to 72% of these cases (Gravani, 2009). Contamination of vegetables, especially by *E. coli* and *Salmonella* has also been reported in many countries including the United States, Mexico, Spain, Brazil, India, Sri Lanka, Philippines, Vietnam, Thailand and Cambodia (Johnston et al., 2005; Quiroz-Santiago et al., 2009; Ruiz et al., 1987; Santos et al., 2010; Tambekar & Mundhada, 2006; Silva et al., 2013; Vital et al., 2014; Chau et al., 2014; Ananchaipattana et al., 2012; Chhay et al., 2017; Kheang, 2016; Hay, 2018).

Among the developed countries, a log reduction value (LRV) of between 1 and 1.5 for *Escherichia coli* and a very low incidence of *Salmonella* (< 1%) was detected in green leafy vegetables in the United States (Johnston *et al.*, 2005). *Salmonella* was found to be present in approximately 5.8% of vegetable samples in Mexico (Quiroz-Santiago et al., 2009), while *Salmonella* and *E. coli* were found to be present in 7.5% and 86.1% of vegetable samples, respectively collected from different market types in Granada, Spain (Ruiz *et al.,* 1987). In 2010, a microbiological analysis showed a high presence by heat-tolerant *E. coli* species in 32% of vegetable samples collected in Brazil (Santos et al., 2010). There are also many reports of bacterial contamination in vegetables sampled in developing countries (Tambekar & Mundhada, 2006; Silva et al., 2013; Vital et al., 2014; Chau *et al.*, 2014; Ananchaipattana et al., 2012; Chhay et al., 2017; Kheang, 2016; Hay, 2018). For example, the presence *E. coli* and *Salmonella* was detected in 38.3% and 5.8% of various types of salad vegetables sold in Amravati city of India, respectively (Tambekar & Mundhada, 2006); in Sri Lanka, the presence of *Salmonella* in leafy vegetables was more common (6% of samples), than *E. coli* (2% of samples) (De Silva et al., 2013); microbiological tests of the quality of fresh produce from open-air markets and supermarkets in the Philippines revealed that 16.7% and 24.7% of 300 samples tested positive for thermo-tolerant *E. coli* and *Salmonella*, respectively (Vital et al., 2014); a study in Vietnam reported that 100% and 17.6% of fresh vegetable samples collected from traditional markets in Hue city were contaminated with *E. coli* and *Salmonella,* respectively (Chau *et al.*, 2014); the presence of *E. coli* was detected in 34% of vegetables collected from open-air markets and supermarkets in Thailand (Ananchaipattana et al., 2012); and surprisingly, the presence of *E. coli* and *Salmonella* species in lettuce leaves from supermarkets in Phnom Penh city (40% and 20%, respectively) was higher than from open-air markets (14% and 10%, respectively) (Chhay et al., 2017).

Vegetables may become contaminated with bacteria, as well as other parasites, during the planting, cultivation, transport, post-harvest processing or preparation of freshly-eaten vegetables (Johnston *et al.*, 2005; Enabulele & Uraih, 2009). Contamination can arise from organic fertilizers, irrigation, soil-borne pathogens, or post-harvest handling (Enabulele & Uraih, 2009; Gosh et al., 2004; Kłapeć & Borecka, 2012; Pachepsky et al., 2011; Ingham et al., 2004; Vital et al., 2014). Many Cambodian farmers still use traditional methods to both produce crops for sale and many risks of microbial contamination may are introduced through some of these methods. Interestingly, there is little mention of microbial contamination of foods in Cambodian, compared to many studies on chemical contamination from pesticides or herbicides (Phoeurk, 2007; Neufeld et al., 2010). Therefore, the importance of this study, investigating the presence and concentration of *Escherichia coli,* total coliforms, and *Salmonella* in freshly-eaten vegetables in Cambodia cannot be understated. This research will raise awareness of the probable contamination thus of these vegetables with pathogenic bacteria and help promote the need for practices that reduce adverse health impacts.

The overall objective of this study is to determine the presence and concentration of *E. coli,* total coliforms, and *Salmonella* in cucumber (*Cucumis sativus*), saw-leaf herb (*Eryngium foetidum*) and lettuce (*Lactuca sativa*) sampled from four different types of markets in Phnom Penh. Specifically this involves (i) determining the prevalence and concentration of *E. coli,* total coliforms and *Salmonella* contamination in cucumber, saw-leaf herb and lettuce collected from different market types in Phnom Penh; (ii) compare the *Escherichia coli,* total coliform and *Salmonella* prevalence and concentration from wholesale markets, roadside markets, mobile vegetable stalls, and supermarkets; and (iii) compare the change in *Escherichia coli,* total coliform, and *Salmonella* concentrations before and after thorough washing under flowing water.

Methodology

The research is based on a cross-sectional study of four types of markets in Phnom Penh, including (i) three wholesale markets (Doeum Kor, Stung Meanchey and Takhmao); (ii) a total of nine road stalls comprising three stalls surrounding each of the wholesale markets; (iii) nine mobile vegetable carts in Phnom Penh; and (iv) nine supermarkets in Phnom Penh (Figure 1). These markets are broadly representative of where most freshly-eaten vegetable purchases are made in the city that accounts for approximately 10% of the total population of Cambodia. Samples of cucumber, lettuce and saw-leaf herb were collected over a period of three months between July and

September in 2017. A total of nine samples of each vegetable were taken from each type of market. This resulted in a total of 36 samples of each vegetable as shown in Table 1. After the sample was purchased, it was transferred to a sterile plastic bag and transported under cool conditions to a laboratory at the Bioengineering Department of the Royal University of Phnom Penh. Each sample was analyzed on the same day as collection. *E. coli* and *Salmonella* bacteria were cultured and a qualitative and quantitative analysis of their presence conducted.

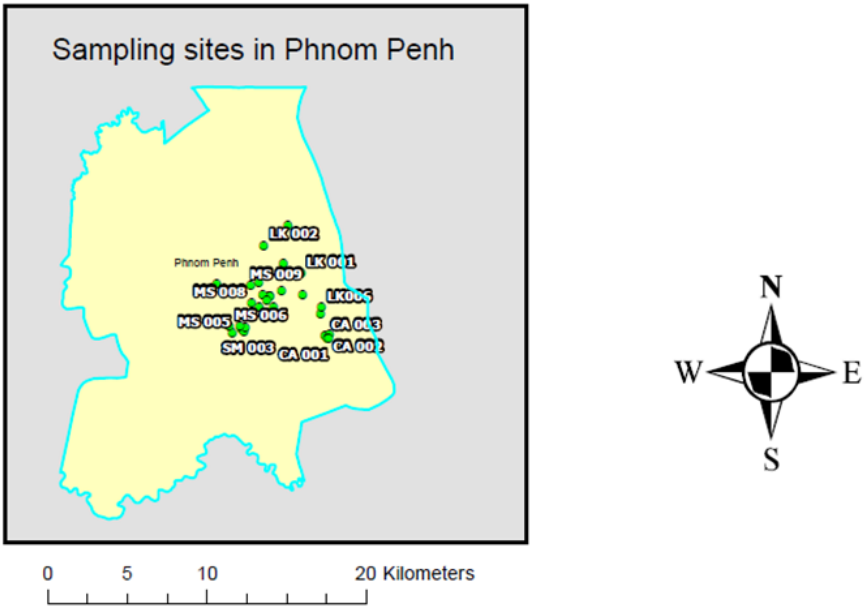
Table 1: The number of water samples collected for this study.

Type of vegetable	**Samples used in this study**		
	E. coli	total coliforms	*Salmonella*
Lettuce	36	36	36
Saw-leaf herb	36	36	36
Cucumber	36	36	36

Sample Preparation

All equipment (knife, tray, glass spreaders, etc.) used for the culturing of bacteria was disinfected with 95% ethanol and a short period of flaming while the glass tubes, falcon tubes and 500ml Erlenmeyer flasks were autoclaved for sterilization. Each vegetable sample was divided in two with one subsample washed under flowing tap water for at least two minutes, while the other was left unwashed (De Silva, *et al*., 2013). Both subsamples were then were minced and 25 g of each subsample was transferred into 225 ml of Tryptic Soy Broth as a substrate for growing the bacteria colonies. The *E. coli* cultures were then incubated at 37 ^{o} C for about 15-20 min while *Salmonella* cultures were incubated at 42 ^{o} C overnight. A ten-fold serial dilution (10^{-1}-10^{-4} for *E.* coli and 10^{-1}-10^{-7} for *Salmonella* spp.) was then prepared from each sample and 25-50 µl of selected dilutions were spread on an agar plate.

Figure 1. Map of sampling sites in Phnom Penh



Analysis of the E. coli samples

A 50 µl aliquot of each sample (10^0-10^{-4}) was spread onto the surface of a Chromocult® Coliform Agar plate (Merck, Germany). The culture plates are then incubated at 37°C for 24 hours and the bacterial colonies inspected for the presence of dark blue to violet color (*E. coli*) and pink to red color (other coliforms). The concentration of each variable was then reported in colony-forming units per gram (CFUs/g). The sterile distilled water used to dilute the samples was also analyzed as negative control.

Analysis of the Salmonella samples

Following analysis for *E. coli,* 1 ml of the Tryptic Soy Broth culture was transferred into 9 mls of Rappaport Vassiliadis Broth, a selective culture broth for *Salmonella*, and incubated at 42°C for 24 hours. The next day, serial dilutions were prepared with sterile distilled water, before 25 µl aliquots (diluted from 10^{-1} to 10^{-4} for cucumber and 10^{-4} to 10^{-7} for lettuce and saw-leaf herb) were spread onto the surface of Salmonella Shigella Agar (Merck, Germany) plates, which were incubated at 37°C for 24 hours. Then, the bacterial colonies on each plate were inspected for the presence of a colorless colony with black center (*Salmonella*). The concentration of *Salmonella* was reported in CFUs/g. The sterile distilled water was again tested by a combination of membrane filtration and the spread plate method for use as a negative control.

Analysis of pathogen removal

The concentrations of bacteria in each of the samples were first expressed in CFUs/g. Then these values were transformed to a $\log_{10}$ reduction value (LRV). To investigate the effectiveness of pathogenic bacteria removal by washing the samples under running tap water, a decimal reduction in the bacterial population was calculated by comparing the colony counts obtained for the unwashed and washed samples. An analysis was then performed using Microsoft Excel.

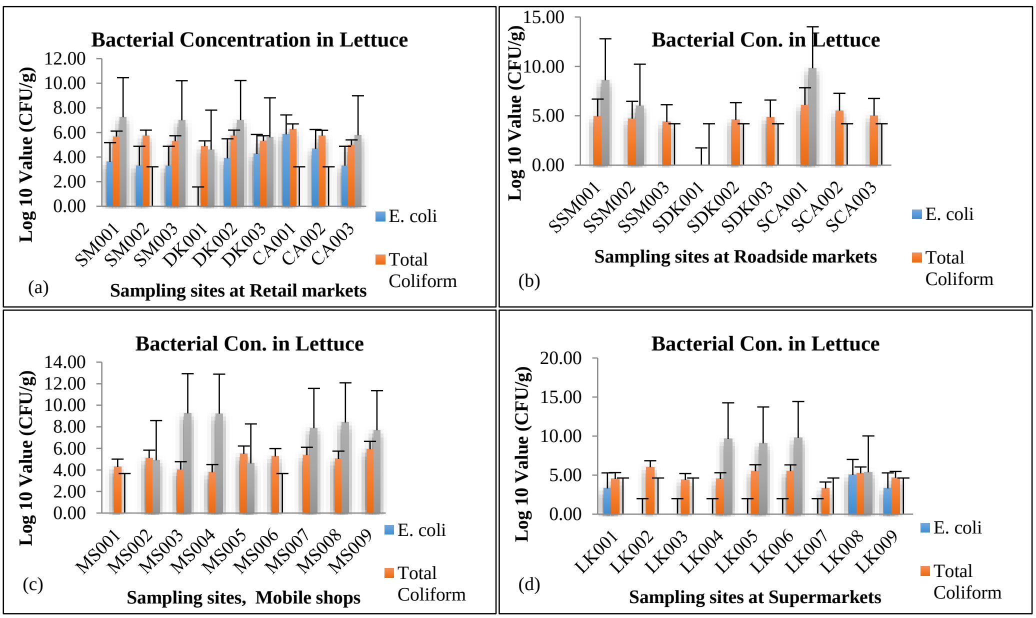
Results and Findings

Samples were collected from four different types of markets including wholesale markets, roadside stalls, mobile vegetable carts, and supermarkets. Wholesale markets such as Chhbar Ampov, Steung Meanchey, and Doeum Kor are the largest vegetable distributors in Phnom Penh and supply produce to most roadside stalls and mobile vegetable carts. Thus, the level of bacterial contamination in each of these samples was expected to be reasonably consistent. In contrast, supermarkets source vegetables from different suppliers. Lettuce, saw-leaf herb, and cucumbers were selected for the study as they are raw vegetables used as preferred ingredients in Cambodian diets. As they are usually not sold or eaten before being washed or cooked, if they are contaminated with pathogenic bacteria, they are a probable infection pathway for foodborne diseases. Lettuce and saw-leaf herb were chosen to represent a broad range of green leafy vegetables, with a large surface area and small surface area, respectively, while cucumbers were selected to represent fruiting vegetables.

Bacterial Contamination in Lettuce

The results for the presence and concentration of *E. coli*, total coliforms and *Salmonella* in lettuce samples from the wholesale markets are presented in Figure 2 (a-d). *E. coli* and *Salmonella* was present in seven and six of the nine samples, respectively, while total coliforms were detected in every sample. This corresponds to an LRV for *E. coli,* total coliforms, and *Salmonella* ranging between 3.30 and 5.85 ($2x10^3$ and $7x10^5$ CFUs/g); 4.88 and 6.26 ($7.6x10^4$ to $1.81x10^6$ CFUs/g); and 4.6 and 7.25 ($4x10^4$ and $1.8x10^7$ CFUs/g), respectively (Figure 2a). No *E. coli* was detected in samples from the roadside stalls, however, eight and three of the nine samples contained total coliforms, and *Salmonella,* respectively. This corresponds to an LRV for total coliforms, and *Salmonella* ranging from 4.38 and 6.10 ($2.4x10^4$ to $1.25x10^6$ CFUs/g); and 6.03 and 9.82 ($1.08x10^6$ and $6.6x10^9$ CFUs/g), respectively (Figure 2b). Although the presence of pathogenic bacteria was less frequent in samples from roadside markets, when it was detected, the concentration was much higher. Like the roadside markets, no *E. coli* was detected in lettuce from the mobile vegetable carts. However total coliforms were present in all samples while seven of nine samples were contaminated with Salmonella. The LRV for values ranged between 3.78 and 5.49 ($6x10^3$ and $8.5x10^5$ CFUs/g); and between 4.60 and 9.26 ($4x10^4$ and $1.8x10^9$ CFUs/g) for total coliforms and *Salmonella*, respectively (Figure 2c). Mobile carts showed a high presence of salmonella, to a very high concentration.

Figure 2. Bacterial contamination in lettuce collected from (a) retail markets; (b) roadside stalls; (c) mobile street carts; and (d) supermarkets in Phnom Penh.



In contrast to expectations, all samples of lettuce collected from supermarkets were contaminated by *E. coli*, while total coliforms and *Salmonella* were present in three and four of the nine samples, respectively. The LRV for *E. coli,* total coliforms, and *Salmonella* ranged between 3.30 and 5.02 ($2x10^3$ CFU and $1.04x10^5$ CFUs/g); $2x10^3$ CFUs/g and $1.09x10^6$ CFUs/g; and $2.4x10^5$ CFU and $6x10^9$ CFUs/g, respectively (Figure 2d). The refrigeration of produce to appropriate temperatures is one of the most important factors in controlling the survival and growth of pathogens (Bolin et al., 1977). It may be that the temperature inside the produce section of supermarkets in Cambodia is supporting rather than reducing the survival and growth of bacteria.

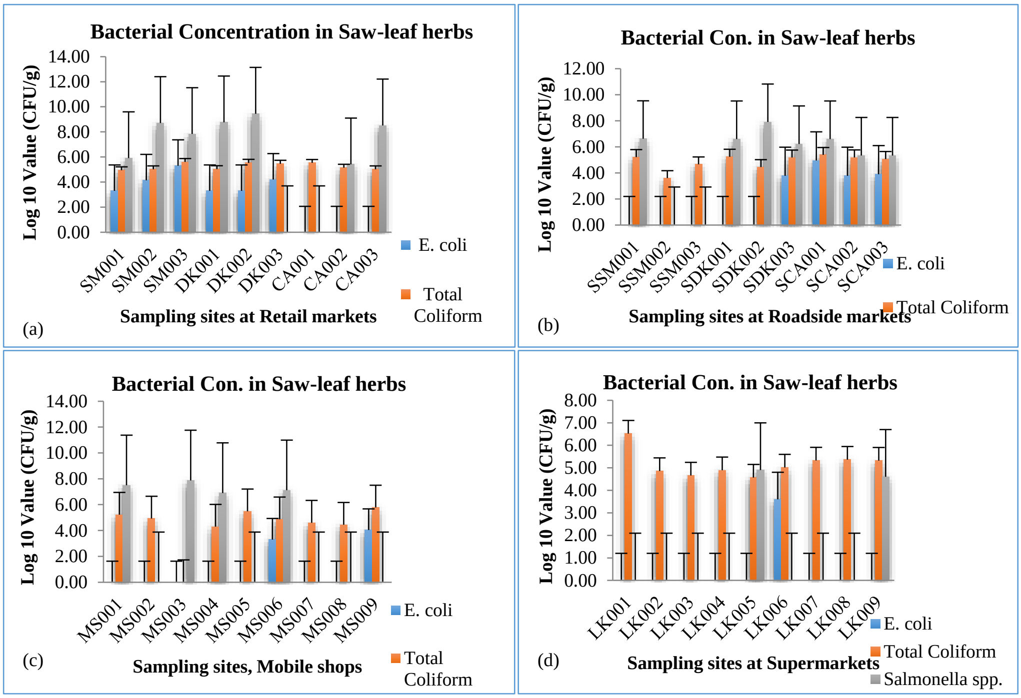
Fresh fruits and vegetables, especially leafy greens vegetables eaten raw are being recognized as the main vehicles for transmission of human pathogens sourced from animals (Berger et al., 2010). While, the internal, uncut tissues of vegetables are sterile, they can become contaminated through the use of organic fertilizers, irrigation, contaminated soil, and post-harvest handling (Enabulele & Uraih, 2009; Gosh et al., 2004; Kłapeć & Borecka, 2012; Pachepsky et al., 2011; Ingham et al., 2004; Vital et al., 2014). A high prevalence of enterobacterial contamination in most of the open-air wholesale markets was found to be common. However, unexpectedly, there *E. coli* was not present in lettuce leaves collected from roadside markets or mobile vegetable stalls. This may be due to bacterial populations becoming stressed by chemical, physical, and biological factors. Examples of microbial stressors include changes in temperature, osmotic pressure, and nutrient availability (Capozzi et al., 2009). It is speculated that the bacteria present in the lettuce leaves, when sold at the retail market for distribution at the roadside markets, and mobile shops may be affected by higher temperatures and experience heat stress, resulting in a lower concentration of pathogenic microorganisms.

Bacterial Contamination in Saw-leaf Herbs

The presence and concentration of *E. coli*, total coliforms and *Salmonella* concentrations in the saw-leaf herb samples are presented in

Figure 3 (a-d). Six and eight out of nine samples of saw leaf herb from the wholesale markets were contaminated with *E. coli* and total coliforms, respectively, while all samples collected from the market contained *Salmonella.* The LRV for *E. coli,* total coliforms, and *Salmonella* were between 3.30 and 5.30 ($2x10^3$ and $2x10^5$ CFUs/g), 4.94 and 5.60 ($8.8x10^3$ and $4x10^5$ CFUs/g), and 5.41 and 9.45 ($2.6x10^4$ and $2.8x10^9$ CFUs/g), respectively (Figure 3a). From the roadside stalls, total coliforms were present in all samples collected, while *E. coli* and *Salmonella* contamination was present in four and seven of nine samples, respectively. The LRV for *E. coli*, total coliforms and *Salmonella* ranged between 3.78 and 4.96 ($6x10^3$ and $9.10x10^4$ CFUs/g), $4x10^3$ and $2.41x10^5$ CFUs/g, and $2.2x10^5$ and $8.1x10^7$ CFUs/g, respectively (Figure 3b). This shows the presence of pathogenic bacteria and the LRV for saw-leaf herbs from roadside markets and retail markets were almost identical. However, unlike the roadside stalls, there was fewer samples containing *E. coli* and *Salmonella* for saw-leaf herbs purchased from mobile carts, with only two and four of nine samples being contaminated, respectively. Total coliforms were present in eight of the nine samples. The colony count for *E. coli*, total coliforms and *Salmonella* ranged between $2x10^3$ and $1.1x10^4$ CFUs/g; $2x10^4$ and $6x10^5$ CFUs/g; and $7.91x10^6$ and $7.5x10^7$ CFUs/g, respectively (Figure 3c). The results for mobile vegetable carts was similar to road stalls with 100% of samples containing total coliforms but only one and two of nine samples being contaminated by *E. coli* and *Salmonella*, respectively. However, the samples that were contaminated had high concentrations of *E. coli*, total coliform, and *Salmonella* species. The single *E. coli* sample had an LRV of 3.60 ($4x10^3$ CFUs/g); while the total coliform and *Salmonella* samples has an LRV ranging between 4.57 and 6.52 (3.7×10^4 and 3.30×10^6 CFUs/g); and 4.60 and 4.90 (4×10^4 and 8×10^4 CFUs/g), respectively (Figure 3d).

Figure 3. Bacterial contamination in saw-leaf herbs collected from (a) retail markets; (b) roadside stalls; (c) mobile street carts; and (d) supermarkets in Phnom Penh

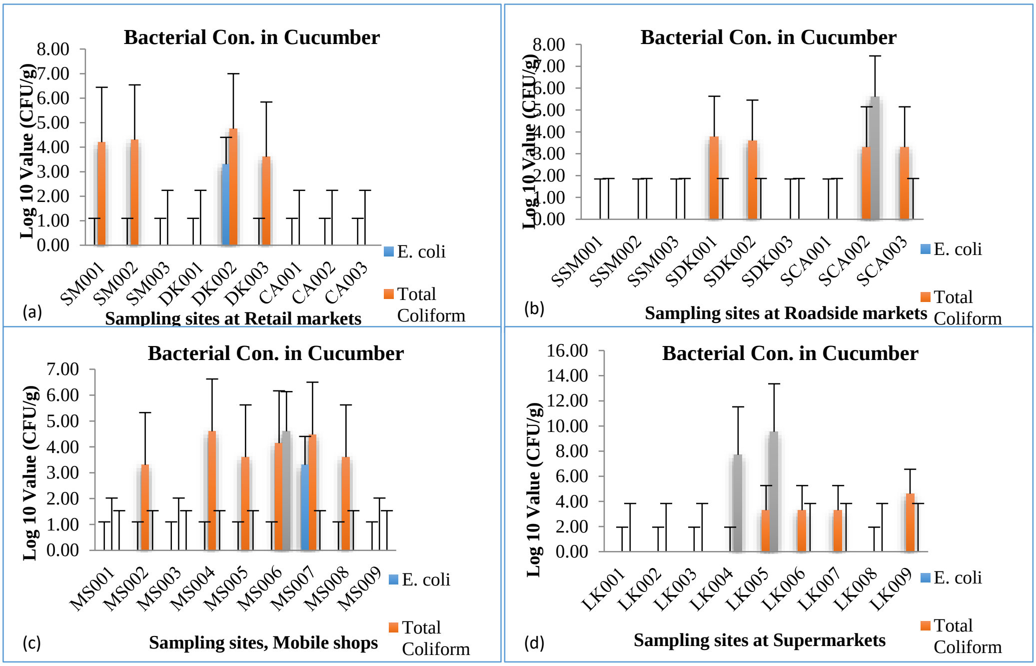


Bacterial Contamination in Cucumbers

The results for the presence and concentration of *E. coli*, total coliforms and *Salmonella* in samples of cucumbers purchased from various types of markets in Phnom Penh are presented in Figure 4 (a-d). Unlike lettuce and saw leaf herb, there was no salmonella contamination detected in cucumber samples purchased from the wholesale markets. One and four of the nine cucumber samples were contaminated by *E. coli* and total coliforms, respectively. The LRV for the sample contaminated with *E. coli* was 3.30 (2×10^3

CFUs/g) and ranged between 3.60 and 4.76 (4x10^3 and 2 x 10^4CFUs/g) for the samples with total coliform presence indicated (Figure 4a).

Figure 4. Bacterial contamination in cucumbers collected from (a) retail markets; (b) roadside stalls; (c) mobile street carts; and (d) supermarkets in Phnom Penh.



From the roadside stall samples, no *E. coli* contamination was found in any of the nine cucumber samples. However total coliforms and *Salmonella* were present in four and one of the nine samples collected, respectively. The LRV for total coliforms ranged between 3.30 and 3.78 (2x10^3 and 6x10^3 CFUs/g), and the sample contaminated with *Salmonella* had a LRV of 5.60 (4 x 10^4 CFUs/g) (Figure 4b). There was a low prevalence and concentration of pathogenic bacteria for cucumbers from the wholesale markets and roadside stalls in general.

The LRV for *E. coli* and *Salmonella* ranged was 3.30 (2×10^3 CFUs/g) and 4.60 (4×10^4 CFUs/g), respectively, and ranged between 3.30 and 4.46 ($2x10^3$ and $4x10^4$ CFUs/g) for total coliforms, which was higher than for the wholesale and roadside markets (Figure 4c). There was no *E. coli* present in cucumber samples collected from supermarkets. However, four and two of the nine samples collected were contaminated with total coliforms and *Salmonella* respectively. The LRV for total coliforms and *Salmonella* ranged between 3.30 and 4.60 ($2x10^3$ and $4x10^4$ CFUs/g) and 7.70 to 9.53 ($5x10^7$ and $3x10^9$ CFUs/g), respectively (Figure 4d).

Table 2. The total proportion of fresh vegetables contaminated with indicator species for bacterial pathogens.

Type of vegetables	**Proportion of total vegetable samples contaminated**		
	E. coli	total coliforms	*Salmonella*
Lettuce	30.7%	97.2%	55.7%
Saw-leaf herb	36.1%	97.2%	55.7%
Cucumber	5.7%	50%	11.1%

Bacterial Removal by Washing

Pathogenic bacteria, such as *E. coli* O157, have been described as bound to the surface of fresh vegetables rather than being contained within tissues (Berger et al., 2010). To test the effectiveness of pathogen removal from fresh vegetable samples, the presence and concentration of each indicator species for each sample was also analyzed before and after thorough washing with flowing tap water. The LRV of *E. coli* in the contaminated samples of lettuce from the wholesale markets was reduced by between 2.5%

and 30% after washing for two of the nine samples while being completely removed in the other two. Most of the *E. coli* bacteria in the saw-leaf herb and cucumber samples were completely removed by thorough washing. *E. coli* in all of the vegetable samples from the roadside stalls (lettuce, saw-leaf herbs and cucumber) were completed eliminated, except for one lettuce sample. *E. coli* presence in all contaminated samples from both the mobile vegetable carts and supermarkets were totally removed after washing. However, washing the vegetables thoroughly under tap water was not found to be effective for removing total coliforms for all types of vegetables in this study (data not shown).

Unlike *E. coli* and total coliforms, the removal of *Salmonella* by thorough washing with tap water was not able to be assessed by this study. A comparison of the tap water with the control (distilled water) found that some of tap water samples used to wash the vegetables contaminated with *Salmonella* bacteria. Therefore, the analysis of these results provided highly skewed data and it was removed from the study. In future studies, experiments will be conducted using sterile distilled water to wash the vegetables to ensure errors are not introduced from other contamination sources.

Conclusion

Overall, this study has shown that majority of the lettuce and saw-leaf herbs sampled from the wholesale markets were contaminated with *E. coli,* while there fewer incidences of the presence of *E. coli* in these vegetables from other types of markets. Total coliforms and *Salmonella* were also present for these leafy vegetables from all types of markets: wholesale, roadside, mobile, and supermarkets. Unlike fresh leafy vegetables, the cucumber samples showed a low prevalence of bacterial contamination, thus presented a lower risk in terms of foodborne disease outbreaks. If fresh cucumber is contaminated, it is easier to reduce the pathogen levels by washing the cucumber with a clean water source. In summary, our data strongly suggests that the fresh leafy vegetables, particularly those with a large surface area, should be washed thoroughly prior to eating. This is also true for fruiting vegetables to remove bacteria and chemicals. This research may be used to raise the awareness of the likely bacterial contamination of fresh, raw vegetables and the risk of adverse health impacts if these vegetables are not washed prior to eating.

Acknowledgment

This study was supported a University Research Grant (2016/17) from the Royal University of Phnom Penh.

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Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Seasonal variation in the nitrate concentration of groundwater samples surrounding the Dangkor Municipal Solid Waste Landfill

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Groundwater is classified as polluted if it contains sufficient chemical or biological contaminants to cause harm to living organisms. Nitrates are a common groundwater contaminant. In developing countries, a common source of nitrates in aquifers is Municipal Solid Waste (MSW) landfills, where they are produced from the decomposition of organic wastes. Nitrate pollution may cause groundwater quality surrounding MSW landfills to deteriorate if the issue is not managed. This research aims to investigate the presence and concentration of nitrates in leachate and groundwater samples surrounding the Dangkor landfill in Phnom Penh and recommend an effective approach for effectively monitoring and controlling these levels. Nitrate levels in leachate sampled from the landfill and groundwater sampled from surrounding tube wells was analyzed to assess (i) the seasonal variation in nitrate concentrations; (ii) spatial variation in the nitrate contamination of aquifers surrounding the landfill; and (iii) compliance with WHO standards. Groundwater samples were collected from three different wells at four sampling points located 500, 1000, 1500, and 2000 m from a reference point at Dangkor MSW landfill. Each sample was analyzed for the presence of nitrates before the concentration was analyzed. The results had several limitations but they suggest that there is no significant relationship between nitrate concentration in groundwater and distance from the landfill. Recorded nitrate levels were well within WHO guidelines for domestic use (50 mg/L) and as such, landfill leachate is not contributing to unsafe nitrate levels in groundwater aquifers between 500 m and 2000 m from the landfill site.

Keywords: nitrates, leachate, groundwater, municipal solid waste landfill

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

To cite this article: Sreng, S. & Proum, S. (2019) Seasonal variation in the nitrate concentration of groundwater samples surrounding the Dangkor Municipal Solid Waste Landfill. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 96–123.

Introduction

Groundwater is water sourced from an aquifer or a porous layer of rock and sand. It is commonly used for domestic purposes such as drinking or washing, as well as for agriculture (Standley 2000). Groundwater accumulates in aquifers through the infiltration of surface water, which needs to be balanced with extraction rates. The quality of water from aquifers may be affected by broad range contaminants as a result of industrial pollution or natural processes (Wakida & Lerner, 2005). One source of groundwater contamination in many ASEAN countries is the burning or dumping of municipal solid waste (Seng et al., 2013; Seng et al. 2011; Ngoc & Schnitzer, 2009). In Cambodia, the dangerous practice of the open burning of solid waste in landfills has only relatively recently declined (COMPED, 2016). The capital of Cambodia, Phnom Penh, is experiencing rapid urbanization, which when combined with rapid population growth has resulted in negative impacts from poor waste management (Mun, 2016). In 2017, 1800 tons of municipal solid waste (MSW) was produced daily in Phnom Penh (Xaypanya et al., 2017). This is expected to rise to 3000 tons per day by 2030 (COMPED, 2013). MSW in the city has been disposed in an open landfill at a 32-hectare site in Dangkor since 2009 when the capacity of the Steung Mean Chey landfill was exceeded and it was decommissioned (Mom, 2009). Leachate management in (MSW) landfills in developing countries is a serious environmental problem. Often, leachate infiltrates surrounding aquifers, causing the domestic water supply of local residents to become polluted.

Nitrates are an inorganic pollutant associated with landfill leachate (Mor et al., 2006). As such, they may be used to indicate groundwater pollution associated with landfills (Ribbe et al., 2008). When landfill leachate enters groundwater reserves, it forms a plume, which spreads in the direction of the flow of the groundwater (Dharmarathne & Gunatilake, 2013). This water requires advanced treatment before it can be safely used. These treatments include distillation, reverse osmosis, or ion exchange (Kapoor et al., 1997). In 1984, the US Environmental Protection Agency (US EPA) stated that open landfills were a major threat to groundwater quality.

Leachate is the liquid component that drains from landfills. It's chemical composition varies widely (Mor et al., 2006). It contains nutrients (nitrogen and phosphorous), microorganisms, salts, and heavy metals and can be hazardous (Dharmarathne et al., 2013; Umar et al., 2010; Kulikowska & Klimiuk, 2008). As water moves through MSW when it rains or floods, leachates may be released and access groundwater reservoirs, which represents a significant risk (Alslaibi et al., 2011; Almasri, 2007). High nitrate levels in leachate can affect both surface water and groundwater quality. This is an issue that has attracted the attention of researchers globally (Jaya & Amir 2015; Bialowiec et al., 2012; Matthews et al., 2009; and Mangimbulude et al., 2007). Some impacts associated with nitrate contamination include: methemoglobinemia, or 'blue baby syndrome', which occurs in young children who consume excessive volumes of water contaminated with nitrates (Ribbe et al., 2008; Gupta, 2001; Gelbrerg et al., 1999; Comly, 1945); stomach cancer; and the eutrophication of water bodies, which produced toxins that reduce the level of available oxygen and impacts biodiversity in aquatic ecosystems. Furthermore, nitrous oxide, a potent greenhouse gas, is produced when nitrates in a water body undergo a process of denitrification (Stanley, 2000).

Cambodia has a tropical climate with clearly defined seasons, a rainy or wet season between May and October; and a dry season between November and April. During the wet season, when there are high levels of precipitation, leachate is more likely to enter aquifers, but in a chemically diluted form. In the dry season, leachate entering aquifers is likely to be of a lower volume but more highly concentrated with contaminants such as nitrates. This study examines the seasonal variation of nitrate concentration in both leachate and groundwater in areas surrounding the Dangkor MSW landfill. If the mechanism of leachate containing nitrates entering aquifers is as described; a gradient in nitrate concentration will be observed along the pathway of groundwater flow from the landfill. This study aims to determine the nitrate concentration in raw leachate being dispersed from the landfill and its impact on the nitrate concentration in groundwater extracted from tube wells surrounding the landfill. The tube wells were selected on the basis of their physical distance from a reference point at Dangkor. Nitrate concentrations in the leachate and groundwater samples from the tube wells was recorded monthly and monitored across a portion of both the wet and dry seasons. These values were compared with the World Health Organization (WHO) guidelines for nitrates in groundwater. This research is expected to provide valuable information for chemistry students, waste management authorities, and residents, who access groundwater surrounding landfill sites for domestic use. It may be used to raise awareness about potential public health and environmental risks associated with leachate contamination of groundwater reserves in Phnom Penh. Dangerous concentrations of nitrate observed when monitoring tube wells would alert citizens of these dangers. However, even concentrations within WHO guidelines are of public interest and may influence hygiene behaviors. It is hoped that this study will result in improved MSW management policies in Phnom Penh and practices that mitigate the risks from leachates, such as the use of a sanitary landfill.

Nitrate contamination of groundwater from the Dangkor landfill

Disposal of MSW in an open dumpsite is a low-cost waste management practice used in many developing countries. When leachate is formed in these landfills and is released from piles of municipal waste, it becomes a source of groundwater and soil pollution (Alslaibi, 2011; Misra & Mani 1991). Landfill leachate is a liquid comprising many contaminants including: dissolved organic matter, such as alcohols, acids, aldehydes; inorganic compounds, such as sulfates, nitrates, and chlorides; heavy metals, such as lead, copper, nickel, and mercury; and xenobiotic organic compounds, such as PCBs and dioxins (Alslaibi, 2011; Mor et al., 2006). Leachate can infiltrate and accumulate in soil and aquifers if a landfill is not effectively sealed. Leachate is transported by groundwater flows and persists in groundwater reserves (Mor et al., 2006; Fadiran et al., 2005). In Cambodia, groundwater from tube wells is often consumed without prior treatment. When hazardous chemicals are present in this water, it may cause harm to domestic water users (Wakida & Lerner, 2005).

Nitrates are produced via nitrification processes in the landfills involving the organic nitrogen present in the waste. Nitrates are a significant component of leachate that is dispersed from MSW landfills. Nitrification, the biological process that produces nitrates, is a process stimulated by two groups of bacteria, *Nitrosomonas* and *Nitrobacter* (Jaya et al., 2015; Stanley, 2000). Common causes of nitrates in groundwater include landfill leachate and nitrate infiltration from fertilizers used in agriculture (Wakida & Lerner, 2005; Standley 2000). Other sources of nitrates in groundwater include wastewater treatment plants and atmospheric nitrogen, which become biologically available after lightning strikes (Anderson & Levine, 1986; Chameides et al., 1977).

Nitrates are usually the most water-soluble component of leachates and the first to be leached into groundwater from the unsaturated zone of MSW landfills (Vinod, 2015). The transport of nitrates is advected and then dispersed by groundwater flows, where it becomes part of the nitrogen cycle via denitrification processes (Pasten-Zapata et al., 2014; Almasri, 2007; Mor et al., 2006). Inorganic sources of nitrates include chemical fertilizers in the form of salts such as ammonium, sodium, potassium, or calcium nitrate (Vinod et al., 2015; Pastén-Zapata et al., 2014; Wakida & Lerner, 2005; Standley, 2000). These salts become dissolved in water at ambient temperatures and pressures. Organic sources of nitrates are derived from the decomposition of plants (Wakida & Lerner, 2005). Nitrates are colorless, odorless, and tasteless when present in groundwater and can only be detected and quantified via chemical analysis (APHA, 1994). Analytical methods for determining nitrate concentrations include UV spectrophotometry, ion chromatography, the use of nitrate electrodes, the cadmium reduction method, as well as others (APHA, 1994). Nitrate-nitrogen (NO_3^--N) present in groundwater samples may be detected first by reducing NO_3^--N to nitrite and then using a coloring reagent. The presence of nitrates in the solution is indicated by an amber color. If present, the nitrate concentration may then be determined using UV-Vis spectrophotometer at a wavelength of 550 nm. The nitrate concentration may then be interpreted in terms of its source and compared with permissible WHO standards for drinking water (Mor et al., 2006). This method is commonly used in the literature for determining the concentration of nitrate ions in groundwater as it is simple to conduct, rapid, and effective, even if there is cadmium contamination present in the sample (Patton & Kryskalla, 2013; Patton & Kryskalla, 2011; Campbell et al., 2006).

There are several impacts that may result from the presence of nitrates in groundwater. For example, methemoglobinemia or 'blue baby syndrome' occurs when infants consume excessive amounts of nitrate (Ribbe et al., 2008). In effect, nitrate is not toxic until it is transformed to a nitrite ion. Nitrite oxidizes and transforms iron in the blood to produce methemoglobin (metHb), instead of hemoglobin (Hb). This interferes with the capacity of blood to transport of oxygen throughout the body (Kim-Shapiro et al., 2005). Stomach cancer is another potential public health risk associated with nitrate pollution. When nitrostable compounds in the human stomach react with nitrite produced from nitrates in groundwater, N-nitroso compounds are formed, which are known to be carcinogenic (WHO, 2011). High nitrate consumption has also been linked to gastric cancer and birth defects (congenital malformations), as well as cardiovascular and thyroid problems

(WHO, 2011, Addiscott & Benjamin, 2004). If groundwater is contaminated with nitrates, it may be treated via a range of physio-chemical processes including ion exchange, biological denitrification, chemical denitrification, reverse osmosis, electrodialysis, or catalytic denitrification. The most feasible method is ion exchange (Kapoor et al., 1997).

Study area and methodology

Dangkor landfill is situated approximately 15 km from the center of Phnom Penh. It commenced operation in 2009 following the closure of another landfill at Steung Mean Chey. The nitrate concentration of raw leachate from the landfill, as well as groundwater sampled from tube wells surrounding the landfill, was conducted for a period of seven months between June and December 2017. Fresh leachate was sampled from a leachate stream draining from a waste pile at Dangkor landfill. Groundwater samples were collected from villages at four intervals from a reference point at the landfill. These villages were all located in Spean Thmor including Ha (500 m), Baku (1000 m), and Prek Chrey I (1500 m), and Prek Chrey II (2 000 m) (Table 1, Figure 3.1). Leachate and groundwater samples were collected monthly over a period of seven months bridging parts of the wet and dry season. For each survey location, three tube wells were selected at random, within a 0.5 km radius of the village from which to collect groundwater samples. Five replicate samples were collected from the pump storage tank of each selected tube well. Similarly, five replicate samples of leachate were collected from the reference point at the landfill. In total, 65 samples (60 x groundwater and 5 x leachate samples) were collected in each sampling run. All samples were collected in 50 mL falcon tubes with no headspace and an airtight cap.

Samples were stored in a cool box with ice and transported to a laboratory at the Royal University of Phnom Penh within three hours of the sample being taken. Upon arrival, they were immediately analysed for nitrate levels using a UV-Vis spectrophotometer.

Each leachate sample was filtered (Whatman, 20 µm filter paper) to remove dense particles. Then, 10 mL of each filtered sample was mixed with NitraVer 5 reagent and shaken for one minute. The mixture was left to stand for ten minutes to observe whether an amber color was present. A color change within 10 minutes indicated the presence of nitrate in the sample. The nitrate concentration of each positive sample was measured using a UV-Vis spectrophotometer (Genesys, 10) at wavelength of 550 nm. The same procedure was repeated for the analysis of groundwater samples (Table 2), eliminating the filtration step. Analysis of results from the spectrophotometer was completed using Beer's law, which shows that nitrate concentration is directly proportional to the absorbance of the samples.

Figure 1. A map of showing the location of MSW landfill, and the four groundwater sampling points.

Source: Google maps, 2018

NB: This map illustrates the locations of groundwater sampling locations at Ha (L1); Ba Ku (L2), Prek Chrey I (L3) and Prek Chey II (L4).

Table 1. Specific location of sampling and the distances from landfill.

Distance from landfill	**Village**
0.5 km	Ha
1 km	Baku
1.5 km	Prek Chrey I
2 km	Prek Chrey II

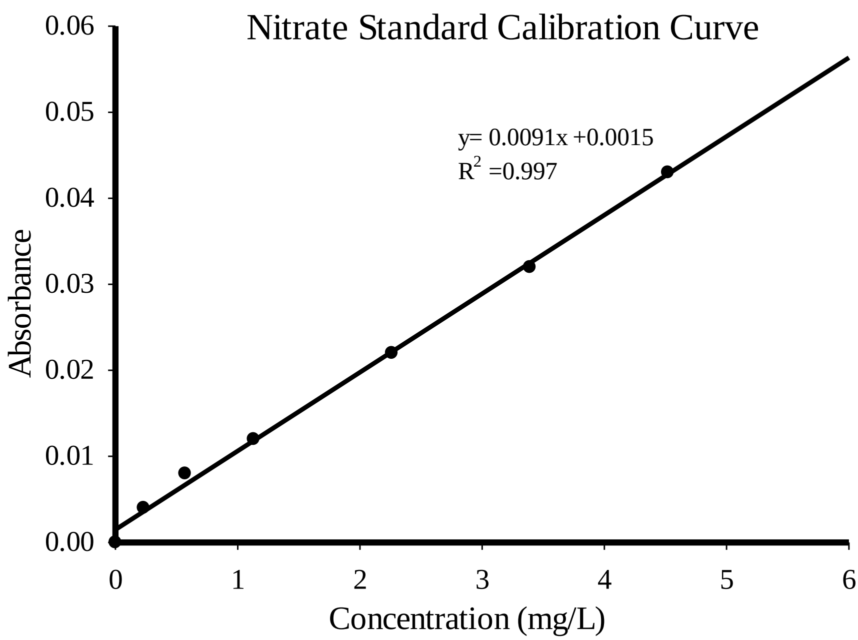
Table 2. Equipment used UV-Vis spectrophotometer (Genesys 10S).

50 mL and 15 mL plastic falcon tubes
Cooling box and ice
Scissors
Filter papers (Whatman, 20 µm)
Micropipettes (5 mL and 1 mL)
NitraVer 5 nitrate reagent (Hach, USA)
Potassium nitrate crystals

A working standard was prepared by dissolving 0.163 g of potassium nitrate (KNO_3) crystals (China) in 1 L of distilled water, with a NO_3^--N concentration of 22.62 mg/L (Figure 2). This was then diluted to a range of concentrations between 0.05 mg/L to 14.50 mg/L. This was used to plot a nitrate calibration curve (nitrate concentration vs. absorbance) using Beer's law. A linear regression was performed (Y = 0.0091X + 0.0015) giving an R^2 of value 0.9970.

The significance of the relationship between the nitrate levels in the groundwater sample at each sampling location was tested using a one-way analysis of variables (ANOVA) test performed using the Statistical Package for Social Science (SPSS). The significance of seasonal variability over the wet and dry seasons was also tested. The aim was to investigate whether the mean nitrate concentration varied significantly across each sampling location. The accuracy of the calibration curve was also tested using a spike recovery method. Nitrate standards were added to samples of unknown concentrations and prepared using the same procedure used for the groundwater and leachate samples. The recovery of the nitrate concentration in the spike samples was found to be within an acceptable range (97 to 116 %).

Figure 2. Standard calibration curve for nitrate.



Findings and Results

Nitrate concentration in groundwater

The results for nitrate concentration (mg/L) in groundwater at the four sampling locations spaced at 500 m intervals from a reference point at Dangkor landfill are shown in Table 3. The nitrate concentration varied greatly across each location and month. The lowest concentration was recorded at Ha village, 500 m away from the landfill in November 2017 at 0.86 mg/L. The highest concentration was recorded at the same site in July 2017 at 14.49 mg/L. However, variation in the data collected at each of the sampling sites was not significant ($p>0.05$, ANOVA test–one way, test) (Table 4). During the monitoring period, the nitrate concentration at each site for all sampling locations varied between approximately 2 mg/L and 8 mg/L, with exception of the tube wells at Ha village (location 1) in July and November.

Table 3. Mean (± standard deviation, n=5) nitrate concentrations (mg/L) for groundwater samples collected between June and December 2017 at incremental distances from the municipal solid waste landfill.

Location	June	July	August	September	October	November	December
1	2.84±1.20	14.49±22.76	2.70±2.22	5.23±2.11	4.26±2.75	0.86±1.04	2.50±0.41
2	5.09±3.14	3.78±1.61	4.31±3.50	5.27±0.61	3.54±1.63	1.66±0.65	4.55±2.48
3	4.27±2.53	5.17±2.86	2.42±1.17	4.38±2.21	5.82±2.70	1.57±1.09	3.04±1.48
4	2.35±1.16	2.01±1.05	6.20±3.54	8.18±6.74	3.22±1.40	1.54±1.20	3.24±3.30

NB: Location 1, 2, 3 and 4 are 500, 1000, 1500 and 2000 m away from the landfill, respectively. A statistical comparison for each month that a sample was taken using an ANOVA test gives values for f and p for each location as 1: 0.804, 0.583; 2: 0.916, 0.512; 3: 1.554, 0.232, and 4:1.687, 0.197, respectively.

In June and November, the nitrate concentration recorded at Baku village (Location 2) was higher than at other locations. If it is assumed that a groundwater plume containing leachate flows sequentially from Ha village

(Location 1) to Baku village (Location 2) to Prek Chey I & II (Location 3 & 4) away from the reference point at the landfill, then the nitrate concentration would decrease from a high value at Location 1 to a low value at Location 4. However, this scenario was not observed for any month during the monitoring period.

To investigate whether the nitrogen concentration varied overall with distance from a reference point at the landfill, data from each location was combined across every month (June to December) and a mean value calculated. This resulted in a nitrate concentration for Location 1, 2, 3, and 4 of 4.7 ± 8.5; 4.0 ± 2.2; 3.8 ± 3.5; and 4.1 ± 4.8 mg/L, respectively. However, no statistically significant relationship effect was identified from this approach (ANOVA test, F: 0.155 P: 0.926).

To test the seasonal effect on nitrate concentration in groundwater, data from all four locations was combining and averaged for the period between June and October (wet season) and November to December (dry season), respectively (Table **5**). There is a clear difference between the levels of nitrates in the groundwater samples between the seasons, with the wet season value (4.78 mg/L), almost double the dry season value (2.45 mg/L).

Table 4. Seasonal effect on nitrate concentration (mg/L) in groundwater

	Wet season (n=60)	Dry season (n=25)	*F*	*P*
Mean ± std	4.78 ± 5.43	2.45 ± 1.84	4.364	0.04

NB: An one-way ANOVA test was performed

The nitrate concentration for all the groundwater samples collected in the study was well within WHO guidelines (50 mg/L) (Figure 2). The guideline is approximately three times higher than the highest nitrate concentration observed during monitoring. In Figure 4, the nitrate concentration in the leachate was shown to be higher than the WHO guidelines. It varied from less than 200 mg/L in November to a maximum recorded value of 550 mg/L in July (Figure 3). The nitrate concentration in the leachate is strongly correlated with monthly groundwater concentrations for Location 1 (r=0.809, Pearson correlation test), and poorly correlated with Locations (2, 3, and 4) (r <0.5).

Figure 3. Mean nitrate concentration for the four sampling locations, compared with the WHO guideline for nitrate concentration in groundwater (red-dotted line).

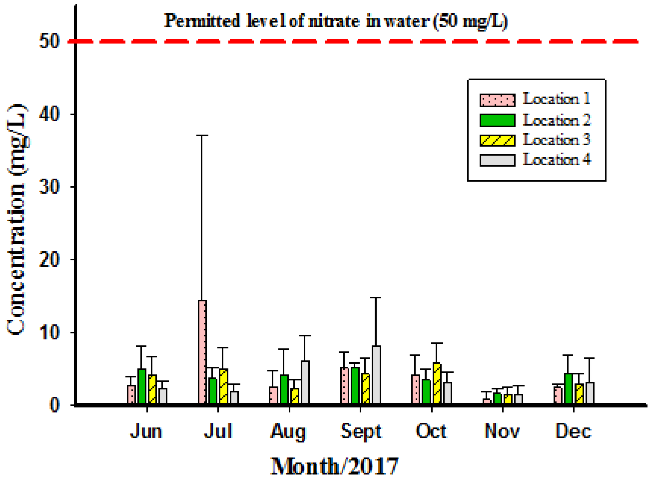
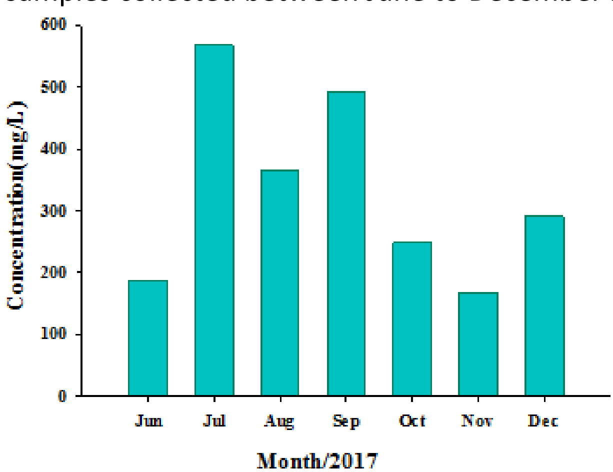


Figure 4. Mean nitrate concentrations (mg/L) for raw leachate drainage samples collected between June to December 2017.



Discussion

The standard nitrate concentration vs. absorbance calibration curve in Figure 2 has an R^2 value of 0.997, which indicates that the standard was not the cause of fluctuating values recorded for nitrate concentration. Table 4.1 shows that highest nitrate concentration recorded during monitoring was 14.50 mg/L in July collected from Ha village, 0.5 km from the landfill site. For a greater distance, 2 km from the landfill site, the recorded nitrate concentrations in the groundwater samples were generally less than 2 mg/L. Excluding the result from Ha village in July, the maximum groundwater nitrate concentration recorded was less than 10 mg/L. The concentration fluctuated, ranging between 2 mg/L and 8 mg/L. The outlying value may be the result of a significant leakage of leachate into an aquifer at that time or low rainfall in July resulting in a more concentrated release of leachate. It may also have been related to the infiltration of fertilizer used in the area.

The lowest values for nitrate concentration, between 0.9 mg/L and 1.5 mg/L, were recorded in November. These results may have been caused by heavy rain in November, diluting the leachate and thus nitrate levels in the groundwater. Overall nitrate concentrations recorded in groundwater between 0.5 km and 2 km from the landfill were much lower than the guideline recommended by the WHO of 50 mg/L. The highest average nitrate concentration was recorded in July at 14.50 mg/L. This suggests that that nitrate present in the groundwater surrounding the landfill does not pose a health risk to residents in the area.

The maximum nitrate concentration recorded in the leachate sampled from the landfill was also in July (550 mg/L), with another high value recorded

September (500 mg/L). These concentrated nitrate values may have been caused by low rainfall in early July and September. The lowest nitrate concentration in the leachate samples was recorded in November, which is when the nitrate values in the groundwater samples were also low.

Table 5 shows that the f-values calculated were always greater than $f_{critical}$-values, and the p-values were always lower than 0.05, except for the November data. This suggests that the linear distance from the landfill in the direction of sampling does not significantly affect the concentration of nitrate in the groundwater. Even in November, the nitrate concentration in the tube wells does not vary with distance from the landfill site as the f-value is lower than $F_{critical}$-value, and the p-value is greater than 0.05.

In some months the recorded nitrate levels in the leachate samples appear to be related to the nitrate levels in the groundwater samples at Ha village (Location 1) but not any of the other sampling locations. However, this correlation was not statistically tested. The poor correlation between the nitrate concentrations at each of the sampling location may be related to hydrogeological conditions and their impact on the groundwater flow that transports the leachate plumes to aquifers at each sampling location. For example, in a study in India, groundwater flow at different depths varied significantly. Leachate transport was more heavily by horizontal flows and percolated much more slowly through the soil profile (Srivastava & Ramanathan, 2008).

The monitoring period used for this study was clearly not sufficient to make conclusions about seasonal variation in nitrate concentration in groundwater samples surrounding the MSW landfill. The collection of localized rainfall data at Dangkor would also enable a clearer analysis of the influence of each season. There was a significant change in rainfall conditions between 2017 and the previous year, which also led to further changes in the recorded concentration of nitrates in this study. This is why the nitrate levels in the groundwater and leachate samples fluctuated throughout the monitoring period. Notwithstanding this, the recorded nitrate levels were significantly lower than WHO guidelines (50 mg/L) for nitrates in aquifers.

Recommendations

This research provides some insight into the impact of leachate from the Dangkor MSW Landfill on nitrate levels in aquifers surrounding the site. The study collected groundwater samples over a portion on the wet season (June to October) and the dry season (November to December) in 2017 and analyzed the level of nitrate present in each sample. However, this investigation has limitations for a number of reasons. Firstly, there is limited data from periods with minimal rainfall. Thus, it is not possible to draw strong conclusions about the seasonal variability nitrate levels due to leachates from the landfill. Secondly, localized hydrogeological conditions for groundwater flow and their impact on nitrate concentrations in the aquifers are not well understood. In effect, the research found a reverse hypothesis for some months. For example, in August and September, nitrate concentrations in groundwater samples increased the further away from the source of the leachate. The mechanism of nitrate contamination from landfill leachate may be different to how they were conceptualized in the experimental design. It may be that other sources of nitrates are also affecting the data such as fertilizers and manure from agricultural production or other areas where organic waste accumulates. Notwithstanding this, the recorded nitrate levels in the groundwater samples in a range of 500 to 2000 m from the reference point at the landfall were significantly lower than the WHO guidelines of 50 mg/L. However, this result is not conclusive, as the monitoring period was limited and not sufficient for understanding the characteristics of groundwater flow in the study area. Any general conclusions made about the impact of nitrates sourced from landfill leachate in aquifers surrounding the landfill needs to take this into account.

The study has documented some short-term observations regarding the nature of negative impacts from nitrates from landfill leachate on the environment in Phnom Penh. However, the seasonal variations and long-term trends associated with nitrate levels in groundwater samples surrounding the landfill are still unknown. This may be addressed in future research by:

- Conducting long-term monitoring of groundwater surrounding the MSW landfills
- Considering how samples are collected from the sampling sites, including the landfill in terms of understanding the mechanisms for leachate (and nitrate) transport in groundwater occur. Samples should be collected at a range of depths to better understand the nature of groundwater flows.
- Considering other potential sources of nitrates in the study area, such as fertilizer and manure from agricultural production, and how they may access aquifers.
- Considering other types of contaminants that the presence of nitrates in groundwater surrounding the landfill may indicate may be indicated such as phosphates and sulfates in leachates, or heavy metals.

Conclusion

This research has monitored nitrate concentrations in groundwater surrounding the Dangkor MSW landfill over a portion of the wet (June to October) and dry (November and December) seasons in Phnom Penh. However, the seasonal impacts are difficult to assess from this data as there is a very limited period of low rainfall assessed, while actual rainfall at the landfill site has not been recorded. In addition, the results obtained were not as expected, with the nitrate concentration often being higher further away from the landfill site. For example, nitrate concentrations at the sampling point at Prek Chey II (Location 4) in August and September recorded some of the highest concentrations of nitrates (6.20 mg/L and 8.18 mg/L) for the entire monitoring period. There are a number of reasons why this may have occurred. Nitrate contamination in groundwater samples may be from other sources. Alternatively, hydrological conditions and soil type may mean the mechanisms for both leachate and nitrate transport in groundwater flows may be significantly different to the original hypothesis. Notwithstanding this, a one-way ANOVA analysis has found that no significant relationship exists between nitrate concentrations in groundwater samples surrounding the Dangkor landfill and the distance from the source of leachate pollution.

However, the maximum level of nitrates recorded in an area of between 500 and 2000 m from the source of 14.50 mg/L is well within WHO guidelines of 50 mg/L for nitrates in groundwater. This suggests that groundwater extracted for domestic users in this zone is safe, in terms of nitrates. However, many unknowns remain with respect to the risks associated with leachate entering groundwater reserves in the vicinity of the

MSW landfill. Future research should consider hydrogeological conditions and soil conditions and how they affect how leachate is transported in the groundwater, other sources of nitrate contamination, and what other types of contaminants may be indicated by the presence of nitrates in the groundwater.

Acknowledgment

This research was supported by a University Research Grant from the Royal University of Phnom Penh. We also wish to express a sincere thank you to our reviewer, Dr Sok Serey from Research office of the Royal University of Phnom Penh who provided comments that greatly enhanced the quality of this paper.

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Annex

Table 5. Statistical data analysis of nitrate concentration in groundwater at each sampling location from June to December

	F	P-value	F critical
June	6.7674	0.0006	2.7694
July	4.9163	0.0042	2.7694
August	7.9958	0.0002	2.7694
September	4.3864	0.0080	2.7826
October	5.6823	0.0018	2.7694
November	2.6170	0.0599	2.7694
December	3.2092	0.0298	2.7694

NB: The values for f were higher than $f\text{-}_{critical}$ values for every month during the monitoring period, except for November, where $f\text{-}_{critical}$ was higher than f. Accordingly, p-values higher were than 0.05 in all months except for November.

Table 6. Recovery Percentages for the nitrate calibration curve

Sample	**C spike (mg/L)**	**C unspike (mg/L)**	**C added (mg/L)**	**%Recovery**
June	10.54	8.11	2.50	97
July	14.72	10.69	3.98	101
August	12.91	8.26	4.00	116
September	10.44	5.96	4.00	112
October	11.75	7.59	4.00	104
November	5.66	1.80	4.00	97
December	4.10	0.09	4.00	100

Table 7. Quality Control

Appointed Conc (mg/L)	Exact Conc (mg/L)
16	16.40
12	12.36
8	8.27
4	2.73
0	0

Table 8. ANOVA analysis result

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	72.24925	3	24.08308	6.767437	0.000565	2.769431
Within Groups	199.2856	56	3.558671			
Total	271.5348	59				

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

An economic assessment of urban flooding in Cambodia: A case study of Phnom Penh

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In development discourse, 'sustainability' is defined as a balance between the environmental, economic and social aspects of a scenario. Economic assessments of the value of natural environments within and surrounding cities, in terms of the ecosystem services they provide, are important for understanding the nature of sustainable development in emerging economies. Ecosystem services play a vital role, providing resources for economic development, regulating environmental flows, supporting livelihoods and well-being, and representing of cultural values such as spiritual or recreational benefits. However, to date, ecosystem services have generally been overlooked in terms of planning and policy decisions in Cambodia. More specifically, in Phnom Penh, the role of wetland ecosystems in retaining stormwater flows for flood protection has not been sufficiently recognized. However, determining the value of urban wetlands in mitigating the impacts of flood events in heavily populated urban areas is complex and difficult to conceptualize. This study assesses this value in terms of the regulating ecosystem services they provide. It achieves this by placing a value on the economic losses experienced in three study areas in Phnom Penh that experience regular rainy season flooding. A mixed methods approach was used to collect the required data for this analysis from 300 questionnaire respondents, as well as through interviews with key informants. The results show that urban flooding is primarily caused by heavy storm events during the rainy season. Economic losses related to these flood events include: vehicle lubricant and other vehicle maintenance, disruption to business activities, and flood recovery costs. Notwithstanding this, the level of flood preparedness by Phnom Penh citizens was found to be very low. These findings suggest that development planners and policymakers should consider urban planning

approaches that place a value on the degradation of urban wetlands to mitigate future economic losses from unsustainable development.
Keywords: urban flooding, storm events, economic losses, public perceptions.

To cite this article: Khan, L. (2019) An economic assessment of urban flooding in Cambodia: A case study of Phnom Penh. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 124–148

Introduction

Phnom Penh was once known as the 'pearl' of Asia, endowed with natural water resources such as streams, lakes, and rivers throughout the city. From a landscape architecture perspective, these resources represented strong aesthetic, social, and ecological values related to sustainability (Englund and Ryttar, 2008). Urban wetlands provide a wide range of ecosystem services to the city. For example, they support a variety of flora and fauna, which contributes to food security and economic development. They also regulate of water flows through the city after rain events, filtering them to improving water quality (Sar et al., 2010). Choeung Ek is the largest urban wetland in Phnom Penh, located five kilometers south of the urban centre of Phnom Penh. It borders the districts of Dangkor and Meanchey, as well as Takmao City, which is the capital and largest city of Kandal Province. Choeung Ek provides Phnom Penh with a broad variety of wild aquatic foods, such as fish, snails, and vegetables (Chea et al., 2010; Sar et al., 2010) and supports the livelihood of many local residents through providing supplementary income. However, the ecosystem functions of Choeung Ek have become degraded over time, affecting these outcomes. Rapid urbanization has caused Phnom Penh to become more vulnerable to the impacts of flooding and caused economic losses (Englund and Ryttar, 2008). Over the last two decades, it has also caused a decline in water quality as a result of the capacity of the sewage system being exceeded (Fortnam & Flower, 2015).

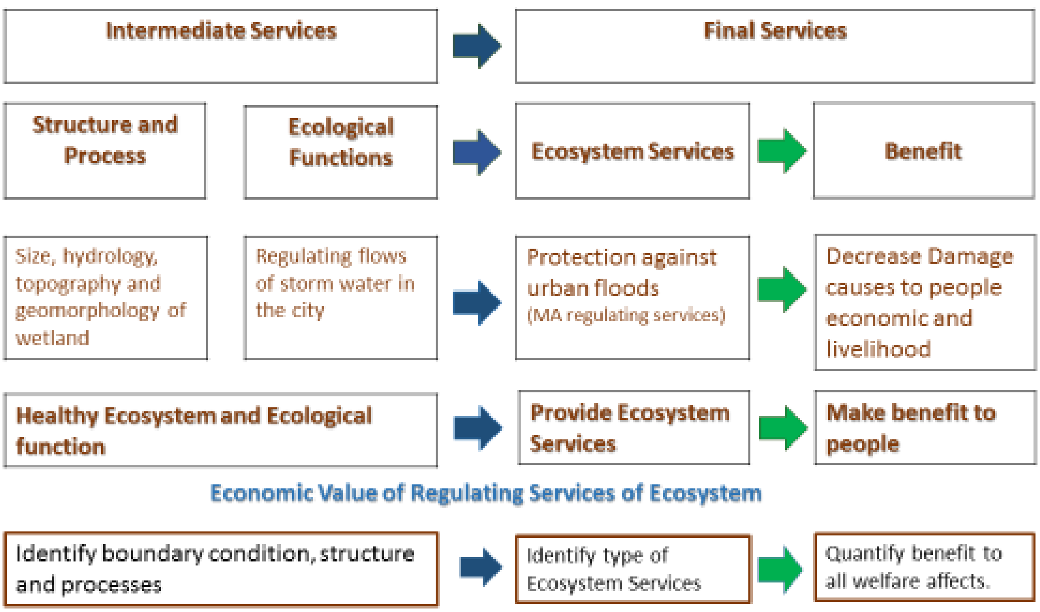
Urban flooding is a common issue in South East Asia and is often overlooked by planners and decision makers (Qin et al., 2013). The problem results largely from unplanned urban development linked to rapid population growth. Master plans developed for sewage and drainage systems are often not sufficient to address increasing infrastructure demands. This problem becomes worse when urban wetlands and natural drainage systems are replaced with impervious surfaces. This increases the intensity of surface runoff and the demand on drainage infrastructure (Ward et al., 2017). Urban flooding also has other negative social, environmental, and economic impacts. This includes traffic disruptions when roads become flooded, pollution of surrounding water bodies, increased public health risks, and economic losses. Rapid urban development in Phnom Penh has led to many wetlands to be filled in and replaced with built infrastructure. The loss of urban wetlands has led to more intense peak stormwater flows, which have exceeded the capacity of drainage systems causing higher flood levels (Qin et al., 2013). This has also led to a need for increased public expenditure on infrastructure for urban flood management.

The persistent degradation of these natural urban assets has not been paid adequate attention by urban planners and policymakers. In the Mekong region, the value of ecosystem services has not been well integrated into urban development policies. This is true in Cambodia, where significant policy gaps exist with respect to ecosystem services (Lebel et al., 2014). Urban planning practices are highly influenced by the need for economic growth and linking the city to the global economy; however, unsustainable urban growth is a significant environmental concern. For example, Choeung Ek currently faces many constraints in terms of its capacity to regulate of peak stormwater flows. High-density urban development is encroaching on areas surrounding urban wetlands causing a degradation of its ecosystem function and negative impacts on public health (Kok et al., 2012);(Wang et al., 2008). Thus, an assessment of the economic loss associated with this degradation through its impact on urban flooding in Phnom Penh is timely. It is anticipated that this research will support urban planners and policymakers to become more informed of both the positive and negative economic impacts of urban infrastructure projects.

This research explores the close association between a loss of capacity of wetland ecosystems in Phnom Penh to regulate stormwater flows and urban flooding. The first objective is to conceptualize the connectivity between the urban flood events and the ecosystem services provided by urban wetlands. This is achieved by defining the characteristics of stormwater flows through the city, how they are connected to infrastructure such as the sewage and drainage systems and major urban wetlands.

This is defined in a conceptual model of how ecological processes and functions are structured in Phnom Penh, as a foundation for the provision of ecosystem services (Figure 1). The second objective is to draw upon local perceptions about flood preparedness and stormwater management to mitigate economic losses from flooding. To be able to characterize the ecosystem benefits of urban wetlands and what is lost when they become degraded, it was important to define the structure of a healthy, functioning urban wetland ecosystem. This was to be achieved by defining a set of boundary conditions such as the size of the wetlands; their physical location, geology, and water balance; pH and dissolved oxygen; as well as seasonal and annual variation in rainfall. Then, the function of the wetland ecosystem services were to be classified by the intermediate services they provided, such as the regulation of stormwater flows; the final services that are supplied such as flood protection; and the direct benefits experienced such as the mitigation of economic losses due to flooding (Turner et al., 2008) (Figure 1).

Figure 1. A conceptual model of the regulation of stormwater flows in Phnom Penh by the ecosystem services provided major urban wetlands.



Adopted from Wood et al. (2010)

This model may have been used to characterize the regulation of stormwater flows by urban wetlands and determine their total economic value. Once the structure and processes of urban wetlands were defined, their ecosystem function could have been clearly specified. Then, the benefits of the ecosystem serviced provided by urban wetlands could have been determined based on whether the benefits are direct, indirect, or non-use values (Turner et al., 2008). Economic losses associated with urban flooding are a result or stormwater runoff exceeding the capacity of the existing sewage and drainage systems. Additional pressures can increase the magnitude of these losses. For example: increased land-use density associated with urbanization places greater stress on existing sewage and drainage systems, which are already insufficient; poor solid waste management, which is a growing problem in Cambodia, causes blockages and damage to existing drainage infrastructure and sharply decreases drainage capacity (Lamond et al. , 2012); and an increasing frequency and intensity of rainfall events associated with climate change makes urban flooding a more significant problem (Miller and Hutchins, 2017). The increasing pressure on the drainage capacity of urban infrastructure in Phnom Penh makes the natural stormwater flow regulation services provided by urban wetlands even more valuable.

Methodology

A desk review was conducted of the existing available literature on the economic assessment of stormwater flow regulation. This was conducted to obtain a broader insight into the ecosystem function of Choeung Ek and other major urban wetlands in Phnom Penh and their connectivity with different flood-prone areas. The conceptual framework outlined in Figure 1 was used to identify the main structural elements of the urban wetland system in Phnom Penh and how they are linked to ecological functions. A review of grey literature obtained from relevant Cambodian institutions was used to become more familiar with the hybrid topography of natural catchments and sewage and drainage systems in Phnom Penh. This led to the selection of three study areas in Toul Kork district for collecting primary data including 1) Kampuchea Krom in Teuk Laak I Sangkat; 2) Depot Market, in Phsar Depo II Sangkat; and 3) the Mondial Commercial Center in Teuk Laak III Sangkat. These locations are all located in the centre of Phnom Penh, regularly experience flood events in the rainy season, and have ecological connectivity to Choeung Ek through the other urban wetlands.

The sites were also selected on the basis of covering different types of urban environments. This included different topographies, as well as both commercial and residential land use. The aim was to be able to compare a range of different perceptions about urban flooding. The first study area was a zone along a major road (Kampuchea Krom), where there is a high density of commercial office buildings. This area includes a campus of the Asia Europe University and Chea Sim Santhormork High School, as well as small businesses and restaurants operating at the street level. The second study area is a zone surrounding Phsar Depot market. The area includes a dense range of small businesses and open markets. By night, there are many temporary stalls selling food, drinks, and clothes. The third study area in Teuk Laak III Sangkat is primarily residential. However, it does include the Mondial Commercial Center, which comprises Klaing Romsav and Neak Meas markets. These are open-air markets selling electronic equipment and other products.

In total, 300 research participants were recruited to complete questionnaires using purposive sampling and a systematic selection of respondents. Every third person was selected to response to questionnaire in the three study areas to avoid encountering previous respondents. In total, 100 respondents completed the questionnaire in each study area: Kampuchea Krom, Depot Market, and Mondial Commercial Center. All respondents lived and worked in the study area including: sellers, police, passengers on public transport, and residents. The aim of the questionnaire was to collect data for determining the economic value of losses associated with urban flooding in Phnom Penh based on these three representative areas with connectivity to major urban wetlands. The basis for determining this value was an average damage function taking into account the value of commercial and industrial activities, buildings, and other infrastructure (Huizinga et al 2017). This approach has been used globally, with indicative data available for many countries worldwide (Huizinga, Moel, & Szewczyk, 2017). Interviews with key informants, such as experts from the Royal University of Phnom Penh were also used to obtain a more complete understanding of the impacts of urban flooding in these areas.

The questionnaire comprised three main parts. The first part focused on general demographic information to understand the context in each study area. The second part focused on collecting information required to determine how stormwater flows are regulated by urban wetlands. This was to be estimated on the basis of an economic damage function, which defines the value of urban wetlands by a comparison with a situation where they don't exist. Actual economic losses experienced by people in each study area from flood events were used to estimate the value of urban wetlands in protecting citizens from these losses. The third part was focused on public perceptions towards flood preparedness and stormwater management to mitigate these economic losses. The methodology was adapted over the course of the study to account for differences in the planned purposive sampling and the willingness and availability of respondents to participate.

Figure 2. A map of the three selected study areas.

The study initially planned to conduct an economic assessment of regulating services of the Choeung Ek wetland, located to the south of Phnom Penh. However, this scope was revised down to an assessment of the economic losses experienced due to flood events in the three study areas due to budget constraints and the capacity to collect sufficient data. The will be used as a starting point for future studies on the value flood regulation services provided by urban wetlands. Flood depth data in the study areas are presented as simple descriptive statistics (maximum, mean (average), and minimum). However, data collected about the scale of economic losses were assessed using an analysis of variance (ANOVA) to determine whether a significant relationship between time of a flood event and the scale of economic losses existed. Additionally, data on public perceptions of urban flooding was analyzed using a Weight Averaged Index (WAI) to gain insight into the impact of local perceptions of urban flood risks and risk reduction activities on the mitigation of economic losses.

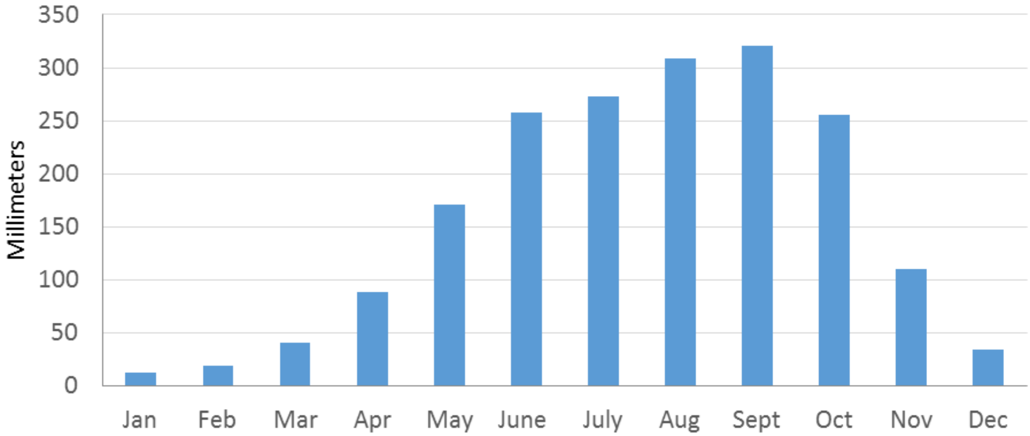
Findings and Results

Severity of flood impacts in Phnom Penh

In Cambodia, a rainy season is usually experienced between May and November. Heavier rainfall events usually occur in August and September, in middle of the rainy season; as well as in November, at the end of rainy season. Average rainfall trends in Cambodia for the period between 1991 and 2015 are presented in Figure 3 (World Bank, 2018). While the total rainfall in between August and September is relatively higher than at the end of the rainy season, flood events in November usually are of longer duration and higher intensity. This results in a higher incidence of flood events with a high flood peak at the end of the rainy season. Observations of flood events in Phnom Penh between September and November reflect this scenario.

A period of higher rainfall intensity usually begins in September (annual average rainfall = 320 mm) and continues into October (annual average rainfall = 255 mm). Generally, flood events occurring in October tend to have a less significant impact on commercial activities. Survey results show that businesses still operate, albeit with less customers. Flood events with a higher peak and duration occur in both September and November. During these months, there are frequent rainfall events, where the capacity of the sewage and drainage systems is exceeded. This strongly influences the level of economic loss experienced. When this capacity is exceeded, the value of urban wetlands (sub-basins), such as Boueng Trabek and Boeung Tumpun; and Choeung Ek (a major drainage basin) becomes more significant. Without their ecosystem function, stormwater would be spread across a larger area of the city, with an increased depth in flood prone areas (Figure 4). This depth varies in each study area depending on topography, localized rainfall characteristics, and the quality of drainage infrastructure.

Figure 3. Average rainfall in Cambodia from 1970-2015.

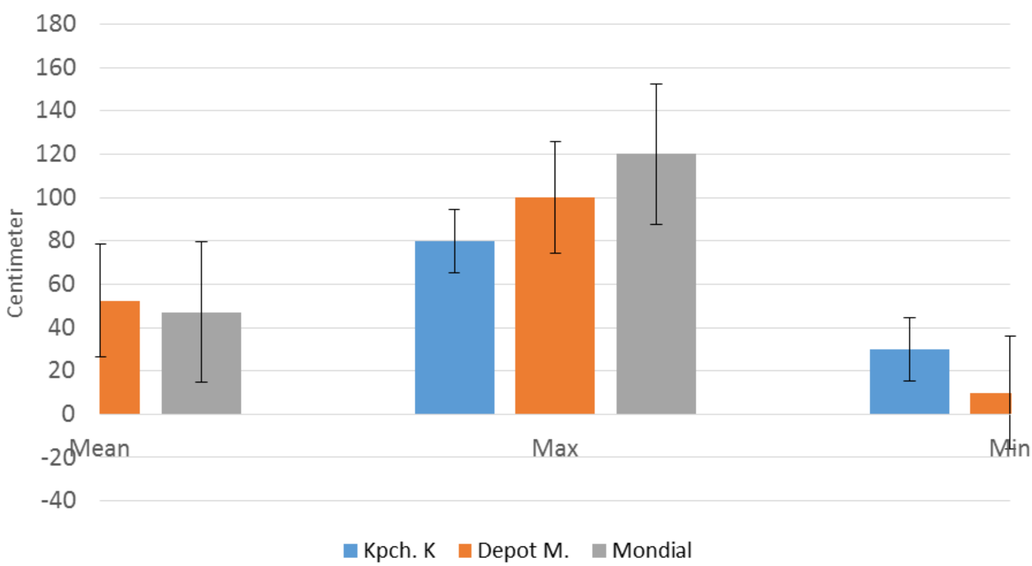


Source: Climate Knowledge Portal World Bank, 2018

Figure 4 shows the descriptive statistics for flood depth in the three areas studied. It also shows that flooding at Kampuchea Krom, while being more widespread than in other areas, only reaches a maximum depth of 80 cm. This is due to being located near Russian Federation Boulevard, a major road, which is sloped and enables water to drain away more rapidly. This reduces the impact on traffic flow in this area. However, the drainage and sewer system at Kampuchea Krom is of a lower standard, resulting in a longer period of time where restaurants and other business are impacted. In addition, the impact of the flood event is transferred to smaller roads and intersections in the area.

The flood levels experienced at Mondial Commercial Center reach a higher level than other locations. Flood levels in this area vary depending on rainfall volume. Heavier rainfall events cause floods to cover main streets and pathways, with of the entire surface of the locality under water. Flooding after medium and heavy rainfall events is attributed to the capacity of the sewage system being exceeded by stormwater runoff. This is made worse by the presence of plastic waste in the sewage system, which increases the duration of flooding and results in higher flood levels than would otherwise be expected. The area has a low topography and water from other areas flows to this location rapidly.

Figure 4. Flood depths reported in each of the three study areas.



Notwithstanding this, flood levels also recede quickly. The area includes Doeum Kor market, which is one of the largest distribution points for agricultural produce in Phnom Penh. It was recently prioritized for drainage infrastructure improvements. Floods here now recede within a few hours of a major rainfall event. One key informant described how this area is one of the lowest in the city, having previously been a wetland. Previously, water naturally accumulating in this area would flow into Boueng Tumpun, which acted as a sub-reservoir to regulate flows to Choeung Ek.

Flood levels at Depot market are not as high as the Mondial Commercial Center but have a more significant impact due to problems with the sewage and drainage system in the area. Floods cover the road at a major intersection near the market reach a level of 100 cm, two or three times per year. This is much higher than regular flood levels of between 10 and 47 cm. Residential areas near Depot market are located on higher ground. However, because of limitations in sewage infrastructure, they flood more frequently than the other study areas.

Table 6. Economic losses related to urban flooding.

Attribute	**Kampuchea Krom**	**Mondial Center**	**Depo Market**	**Overall**
Lubricant replacement	3.34	2.38	4.45	3.50***
Vehicle maintenance	2.59	4.12	5.07	3.97
Trading losses	0.72	0.63	0.51	0.62
Flood damage recovery (businesses)	32.20	31.57	22.81	29.24

In each of the study areas, commercial activities are suspended or cancelled when floods cover the road. This may last for a period of between 20 minutes or a few hours depending on the intensity of the rainfall event. These are direct impacts from flooding. Other economic losses are experienced due to vehicle maintenance costs and traffic congestion. These are indirect impacts from flooding. When major roads are flooded, motorists tend to commute using other roads to avoid potential damage to vehicles. This transfers traffic problems to other areas not directly affected by floods. Flooding has an impact on traffic movement and travel times across the entire city. Residents who live in flood-prone areas also suffer vehicle damage if they do not have a safe place to park their vehicle. The economic loss profiles due to urban floods are differentiated for each of the three study areas.

The economic impact of urban flooding in each of the three study areas is significant (*P-value = 0.005*). During flood events, economic activities were halted for few hours due to the duration and intensity of storm events. Most businesses are affected, however, these activities continue after floods recede. Damage occurs to vehicles traveling through the area during flood events. The survey results show that economic losses relate to replacing lubricant and vehicle maintenance. The value of these losses is shown in Table 6, which provides amounts scaled in terms of US dollars. Other losses associated with transportation include traffic as commuters choose routes with no flooding and the number of vehicles on these roads increases sharply increasing travel time and causing traffic congestion. This causes commuters to feel stressed and significantly impacts commercial activities due to lost trading time.

For example, a bakery located near the Mondial Commercial Center intersection shown while flooding in Figure 5 indicated in their questionnaire response that their business declined dramatically during flood events as customers are not able to access the bakery. Flood events such as this cause business disruptions lasting more than four hours. However, high rainfall events that occur during the evening or at night have a lower impact. Other economic losses reported included damage to items sold by businesses. For example, a second-hand computer shop in a flood zone at Mondial Commercial Center reported losses from water entering their premises and damaging equipment, which is more significant in this study area, where flood levels are higher than others. Majority of the economic losses in the study are associated with business recovery from this type of situation.

Figure 5. A flood event observed at the intersection neat the Mondial Commercial Center.

According to results of the questionnaire, urban flood events experienced in Phnom Penh usually last for a maximum of three hours and occur during the middle and at the end of each rainy season. Questions were asked about each respondent's perception about the risks associated with urban floods across a number of different categories including disaster management, public hygiene risk, the loss of urban wetlands, and the provision of public information about flooding. These perceptions were recorded as a weight averaged index (WAI) measured on a five-point scale from considerably less (0.00 - 0.20) to less (0.21 – 0.40) to moderate (0.41 – 0.60) to high (0.61 – 0.80) and to very high (0.81 – 1.00). The results of the WAI are presented in Table 7.

Table 7. Perception of people in study area on flood preparedness and stormwater management.

Attributes	**Kampuchea Krom**		**Mondial Center**		**Depot Market**		**Overall**	
	(n=80)		(n=129)		(n=91)		(n=300)	
	WAI	OA	WAI	OA	WAI	OA	WAI	OA
Disaster management	0.23	L	0.22	L	0.21	CL	0.13*	CL
Hygiene during flood	0.16	CL	0.22	L	0.25	L	0.22*	L
Flood related to wetland loss	0.17	CL	0.17	CL	0.14	CL	0.16*	CL
Information about flood	0.09	CL	0.08	CL	0.35	L	0.23*	L

Note: The WAI was measured on a five point scale [Considerably Less (CL) =0.00 - 0.20, Less (L) = 0.21 – 0.40, Moderate (M) = 0.41 – 0.60, High (H) = 0.61 – 0.80, Very High (VH) = 0.81 – 1.00; OA = Overall Assessment; *Significance at the 0.05 Level; **Significance at the 0.01 level.

Disaster management was perceived as “less” in each of the three study locations and “considerably less” overall. All other WAI responses in the three locations related to public hygiene, the loss of urban wetlands, and public information regarding floods were ranked as “considerably less” on the WAI, except for public information in Depot market which was rated as “less”. This shows that most people in Phnom Penh get little information and about disaster preparation, disaster management, public hygiene during flood events. In addition, citizens in Phnom Penh do not perceive that the intensity of flooding in the city is caused by the loss of urban wetlands, as indicated by a WAI score of less than 0.20. The WAI suggests that most households in the study area have little knowledge of stormwater management or flood preparation practices. For example, most respondents indicated that they had not received any training in flood preparation or stormwater management.

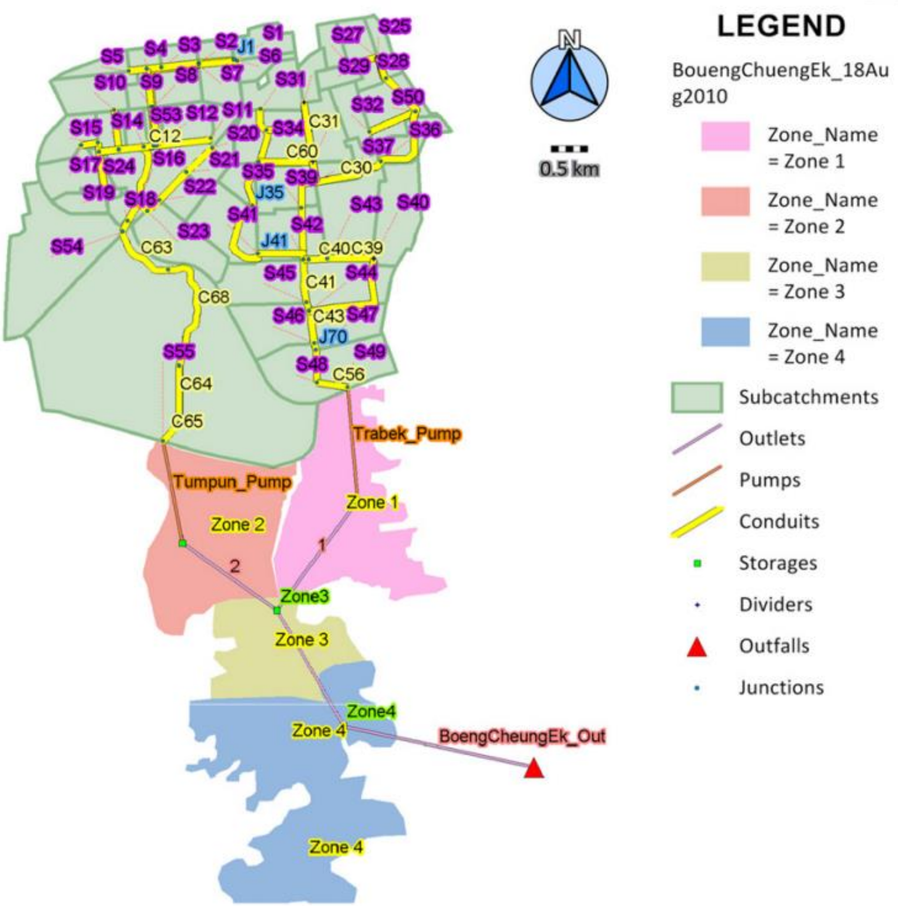
Discussion

The three main research objectives of this study were to: 1) determine the characteristics and depth of urban flood events in the three study areas, 2) explore the economic losses associated with flood events, and 3) measure citizen perceptions of preparedness for urban floods in the study areas.

Stormwater generally flows to sewers and low lying surfaces in the city before it is transported by infrastructure or natural processes to reservoirs or wetlands. Figure 8 shows a schematic of stormwater flows in Phnom Penh (Irvine et al., 2015) and provides more detail. In the case of Phnom Penh, stormwater initially flows toward two sub-reservoirs (Boueng Tumpun and Boeung Trabek). Without these two wetlands, the volume of stormwater in the city would overload sewers and drainage systems to a higher degree and flood a larger surface area. Thus, water from the sewage system would also be spread more widely. The wetlands enable more water to flow into sewers and drains, accelerating the rate at which urban floods recede. Once the flow of water in the sewer is reduced, the water held in the two wetlands is then able to flow to Choeung Ek, where the water is treated. Thus, Boeung Tumpun, Boueng Trabek, and Choeung Ek play a significant role, as urban wetlands, in reducing economic losses associated with flood events. If urban development encroaches upon these wetlands, they will lose their capacity to retain stormwater and the level of economic losses experienced in flood-prone areas of Phnom Penh will increase. Flow regulation services provided by these wetlands have a significant value. However, this value could not be detailed in this paper due to time and budget constraints. If these constraints did not exist, this information would be of significant public interest.

The scale of economic losses related to urban flooding in Phnom Penh has not been addressed in the academic literature. Low level flooding in Phnom Penh imposes many opportunity cost on urban residents. This is a significant barrier to meeting urban sustainable development indicators in Phnom Penh. Urban planning to address regular flood events in the city is relevant to a broad range of these indicators related to sustainable transport, infrastructure development, energy efficiency, environment protection, green growth, public recreation areas, social equity, education, and equitable socio-economic development (Tanguay et al., 2010). Urban flooding affects progress toward urban sustainable development. It causes economic losses and disrupts connectivity between different parts of the city, resulting in greater opportunity costs for socio-economic development. However, results from this study show that flood levels in Phnom Penh of around 50 cm are not considered to be considered a disaster with respect to the global flood damage function (Huizinga et al., 2017). This means that flood levels experienced regularly in the rainy season in Phnom Penh need to be managed differently to a disaster, as the scale and profile of damage is different. Table 8 presents information about the global flood damage index for Asia showing the relationship between flood depth and damage to transportation systems (Huizinga et al., 2017).

Figure 8. Schematic map of stormwater flows in Phnom Penh.



Source: Irvine et al (2015)

Figure 8 shows that flood levels most regularly experienced in Phnom Penh correlate to a flood damage function for transportation systems of less than 0.57. This means that assuming an income of 10 USD per day, the economic loss experienced by a citizen in Phnom Penh related to transportation system damage, would be less than 5.7 USD if flood impacts were experienced over an entire day.

Table 8. Damage of urban flood on transportation.

Flood Depth (Meter)	Damage function in Asia	Kampuchea Krom (Meter)	Depo Market	Mondial commercial center
0	0	0.3	0.1	0.1
0.5	0.36	0.5	0.54	0.47
1	0.57			
1.5	0.73			
2	0.85	0.8	1	1.2
3	1			
4	1			
5	1			
6	1			

Source (Huizinga, et al., 2017)

However, as flooding in Phnom Penh tends to last for a maximum of three hours, this loss needs to be adjusted to a value proportional to the amount of time lost in one day. For example, if the flood affected three of the five hours, usually spent generating income, then this is equivalent to an economic loss of 3.4 USD for the flood event. As the duration of a flood event in Phnom Penh can range from twenty minutes to three hours, this has a significant impact on the value of economic losses experienced due to a flood and hence, the value of ecosystem services provided by an urban wetland.

Conclusion

Urban flooding caused by intense rainfall events results in economic losses due to various factors such as replacing lubricant in vehicles, other vehicle maintenance, time lost due to heavy traffic congestion and flooded roads, and disruption to commercial activities. After heavy rainfall events, the volume of surface water in Phnom Penh exceeds the capacity of sewers and drainage systems, as well as urban wetland systems. Land-use changes in Phnom Penh over the past ten years have seen most of the vacant land in the city transformed to impervious surfaces and roads, which do not allow water to penetrate into the soil. Runoff from hard surfaces causes short term flooding, however, high water levels usually recede within one to three hours of the rainfall event. This water eventually flows into Choeung Ek at the edge of the city. This wetland has a capacity to receive a large volume of water, which reduces the intensity of flood events and associated economic losses. Without urban wetlands such as Choeung Ek, stormwater would take longer to be transported through sewers and drainage systems. This would increase the duration and height of flood events, resulting in more significant economic losses. The majority of these losses are related to the disruption of commercial activities.

While economic losses caused by urban flood events are less significant than flooding that occurs in rural areas, they still require timely intervention. Flood levels in the study areas ranged from 10cm to 120 cm and the time for them to recede ranged from 10 minutes to 3 hours. Questionnaire respondents in Phnom Penh demonstrated a low awareness of management approaches used to mitigate the impacts of these economic losses in flood-prone areas. Many citizens perceive that urban flooding is a natural phenomenon that cannot be avoided. They have limited experience in adapting to urban floods. A lack of capacity in preparing for floods reduces the resilience of the city making citizens more vulnerable to the impacts of flood events. This is significant as they are expected to have a longer duration and become more intense in the future due to climate change. This will in turn increase the vulnerability of urban residents of Phnom Penh, especially when considering other pressures on urban wetlands such as a rapidly growing urban population.

This study recommends that a greater focus be placed on urban planning to achieve sustainable development outcomes. To do this, it is important to better understand the ecological function of urban wetlands and their hydrological connectivity to engineered drainage and sewer systems. The effective management of urban flooding will require a cost-benefit analysis to be applied to the design of urban drainage infrastructure. This report has developed further insights into the requirements of estimating the total economic value of the ecosystem services that urban wetlands, such as Choeung Ek provide in terms of flood regulation. However, while this valuation would be highly useful for urban planners and decisions makers in Phnom Penh, it has not yet been completed due to budget limitations. It is recommended that a future study completes this work.

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Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Lessons learned from the implementation of University Research Grants (2017−2018) at the Royal University of Phnom Penh

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Research is the key to knowledge generation and innovation. It is a key assessment criterion for university ranking systems, which emerged globally in the early 2000s. These ranking systems are used by many national governments to inform the process of allocating public research funds. While this practice is not yet in place in Cambodia, the Royal University of Phnom Penh (RUPP), one of the oldest and largest universities in Cambodia, is attempting to promote a research culture within the institution through the provision of the University Research Grants (URGs). This policy brief illustrates how RUPP has managed the launch, implementation, monitoring, and evaluation of its first URG cycle and share what has been learned.
Keywords: university research grants, research capacity, higher education institutions, university rankings, Royal University of Phnom Penh

To cite this article: Chet, C. (2019) Lessons learned from the implementation of University Research Grants (2017−2018) at the Royal University of Phnom Penh. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 149–164

Introduction

Groundwater is water sourced from an aquifer or a porous layer of rock and sand. It is commonly used for domestic purposes such as drinking or washing, as well as for agriculture (Standley 2000). Groundwater accumulates in aquifers through the infiltration of surface water, which needs to be balanced with extraction rates. The quality of water from aquifers may be affected by broad range contaminants as a result of industrial pollution or natural processes (Wakida & Lerner, 2005). One source of groundwater contamination in many

Background

Global university rankings emerged in 2003 when the Academic Ranking of World Universities (ARWU) was released. This was closely followed in the same year by the Quacquarelli Symonds World University Rankings (QSWURs) and the Times Higher Education World University Rankings (THEWURs) the following year (Soh, 2013). As university ranking systems have become more recognised and influential, university administrators worldwide have developed strategies to improve their performance in these metrics (Grewal, Dearden, & Lilien, 2008). As an example, the THEWURs are global performance tables that assess research-intensive universities across thirteen performance indicators. These indicators are grouped into five areas, including: (1) teaching, or the quality of the learning environment; (2) research, in terms of reputation, public funding received, and productivity; (3) citations, or the influence of research output; (4) international outlook, or the ability to attract students and research collaboration with other countries, and (5) industry income, or revenue sourced from the commercialization of research (THE, 2016). Globally, higher education institutions (HEIs) have adapted their policies and practices based on these rankings to enhance their chances of securing public research funding.

To date, not a single Cambodian university has appeared in the global university ranking system. In Cambodia, academic league tables to evaluate the performance of universities are not yet available. As such, public research funding cannot currently be allocated on the basis of world university rankings. However, Cambodia cannot afford to be left behind. In an attempt to make this transition, a domestic university ranking system based on a non-academic league table has been introduced by an international higher education directory called 'uniRank'. It provides rankings for eligible Cambodian Universities based on valid, unbiased, and non-influenceable metrics from independent web intelligence sources, rather than directly from universities. To be eligible to receive a ranking, universities are required to: (1) be accredited; (2) offer four-year undergraduate degrees and/or postgraduate degrees as a minimum entry requirement; and (3) deliver predominantly face-to-face courses[2]. In 2018, uniRank provided a non-academic ranking for 52 eligible Cambodian HEIs. Currently, the Royal University of Phnom Penh (RUPP), one of the oldest and largest universities in Cambodia, is at the top of these rankings.

In recent years, RUPP was selected to showcase best-practice performance by HEIs in Cambodia by relevant government agencies in Cambodia, as well as international organizations, such as the World Bank. In response, the RUPP 2014-2018 Strategic Plan established a vision to be a flagship university for teaching, research, and community service. In this paper, I will focus on analyzing the research capacity of the institution. RUPP is widely considered to be the nation's leading HEI, in terms of research outcomes. For example, a recent search for international peer-reviewed research publications including an author with an institutional affiliation in

[2]See more detail at https://www.4icu.org/kh/

Cambodia in Scopus, a worldwide abstract and citation database returned 2,787 results. Of the publications listed, RUPP is the only Cambodian University in the top 10 in terms of affiliated authors (Chet, Ford, & Ahrens, forthcoming). However, if RUPP, as the leading research institution in the country is to be included in the world university ranking system, significant investments in the research capacity of the institution are vital. This outcome would be a clear indication that Cambodia has made progress in improving its capacity to generate knowledge and innovation within the country and is better equipped to address challenges related to improving its socio-economic development indicators.

In 2017, RUPP introduced the first iteration of the 'RUPP Faculty Research Fund' pilot, which allocated university research grants (URGs) to faculty members and staff at the university. The five journal articles, published in this volume of Insight: 'Cambodian Journal and Basic and Applied Research' represent the research output arising from some of these URGs. This policy paper will draw attention to both the successes and challenges faced when implementing this initiative in terms of the allocation and administration of the fund.

Allocation of the University Research Grants

During the 2017-18 academic year, RUPP hosted 17,644 students, either by scholarship or payment of a fee. RUPP is unique in Cambodia in terms of offering a broad range of degrees and other professional programs in science, engineering, information technology, and the social sciences and humanities. The teaching and research profile related to these course offerings has enabled the institution to attain full membership of the ASEAN

University Network (AUN). Currently, of the 1,023 staff members at RUPP, over 88% hold a Bachelor's Degree, close to half hold a Masters qualification, and 78 have a PhD (see Table 1). RUPP also draws on the expertise of adjunct faculty members working in local and international universities and NGOs, as well as government ministries. The 'RUPP Strategic Plan 2014–2018' envisions the institution as a leading research hub and think tank in Cambodia. The university is committed to establishing an enabling environment for a research culture to develop within the institution and this is reflected in university policies.

Table 1. Qualifications of teaching and non-teaching staff at RUPP.

Staff Category	**Non-degree**	**BA/BSc**	**MA/MSc**	**PhD**	**Total**
Government staff	28	55	331	41	455
Local contract staff	91	239	157	21	508
Expatriate staff	-	29	15	16	60
Total	**119**	**323**	**503**	**78**	**1023**

Source: RUPP Personnel Office (2017)

A key component of these policies was to pilot the RUPP Faculty Research Fund. This pilot was intended to provide URGs to faculty members to conduct and publish research in national, regional or international journals. The allocation and administration of the grants was overseen by a Research Committee chaired by the Vice Rector of Research, as well as the Head of the Research Office and a Deputy. The committee comprised eight other members representing each of the main Faculties/Institutes of the university. In total, 80,000 USD was allocated by this committee through the Research Office. Three categories of URGs were allocated: five large grants of 5,000

USD; ten medium grants of 3,000 USD; and nineteen small grants of 1,000 USD. The remaining budget was allocated to facilitating research workshops to administer the funds.

The Research Office developed financial and administrative procedures and guidelines to govern how the URGs would be allocated to both teaching and non-teaching staff. University staff were informed of the nature of the grants, how to apply, and the financial and administrative requirements for grant recipients during two workshops held on-campus. They were also offered further opportunities to consult with the Research Office when preparing their application. In total, the URGs attracted 44 applicants: 23 for the large grants; 15 for the medium grants; and 6 for the small grants (Figure 1). The clear preference of applicants for large grants is considered be representative of the high costs of conducting high-quality research for items such as the purchase of laboratory equipment and a budget for field work. Each applicant was required to submit a proposal including a curriculum vitae and a list of past publications, if relevant. Each research proposal was evaluated by two independent reviewers, with an academic background in either science or the social sciences. Assessment criteria were applied by the reviewers to assign a rank to each application based on a possible score of 100 points. The criteria (Figure 2) were developed by the Research Office and approved by the Research Committee. Two independent reviewers were used to align with the principles of transparency and accountability and enable staff to participate in the evaluation. It is envisaged that this procedure may be promoted as best practice for other HEIs in Cambodia intending to replicate the RUPP Faculty Research Fund.

Figure 1. Number of available grants vs. number of applications by grant category.

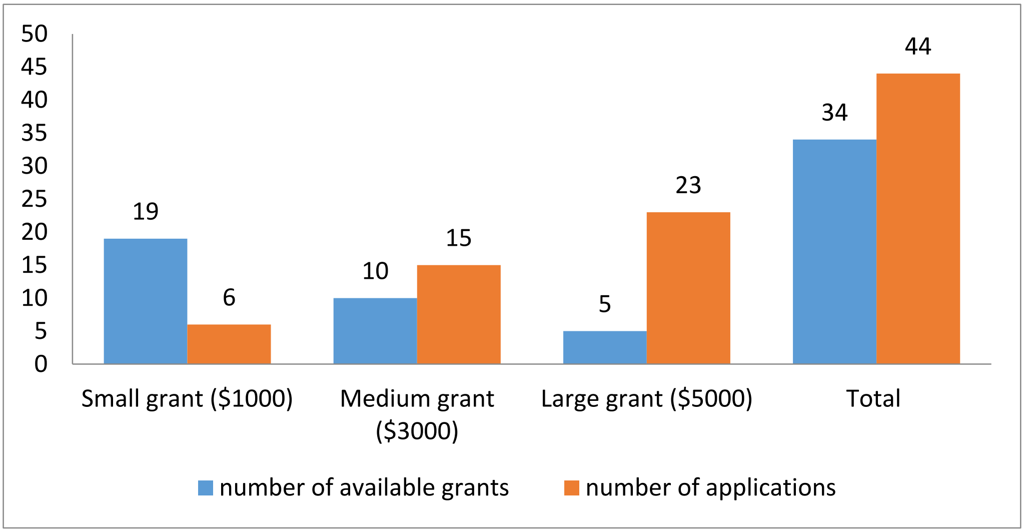
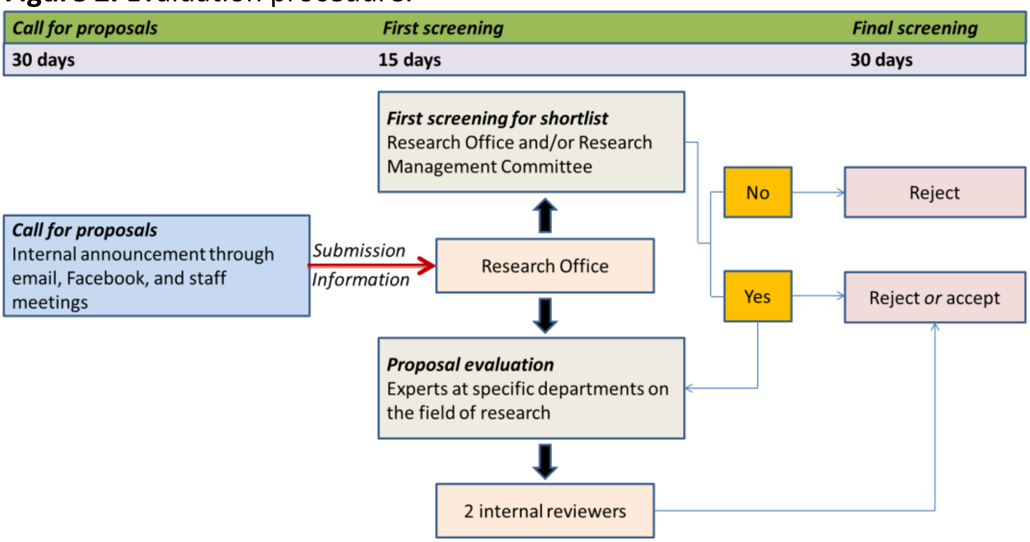


Figure 2. Evaluation procedure.



A Research Committee meeting was held to discuss the evaluation of the proposals and select the successful grantees, primarily based on the scores provided. The number of grants awarded in each category needed to be adjusted to account for a mismatch in the number of proposals received for each grant category. In total, 24 grants proposals were accepted, comprising 7 large, 11 medium, and 5 small grants, with at least one large grant awarded to each Faculty/Institute/Office that applied. The distribution of the grants is detailed in Table 2. One of the small grants awarded to the Faculty of Engineering was withdrawn after the results were announced and as a result only 23 proposals were actually implemented.

Table 2. The number of proposals submitted, accepted and implemented by each Faculty/Institute/Office.

Faculty/Institute/Office	Proposed	Accepted	Implemented
Faculty of Science	14	7	7
Institute of Foreign Languages	7	4	4
Facility of Development Studies	6	4	4
Faculty of Engineering	4	3	2
Faculty of Social Science and Humanities	10	3	3
Other offices	2	2	2
Faculty of Education	1	1	1
Total	**44**	**24**	**23**

Administration of the University Research Grants

The Research Office was assigned to administer the URGs based on the monitoring and evaluation framework outlined in Figure 3. Upon being selected, grantees were able to access 30% of the URG to conduct field work or experiments. A second installment of 50% was accessible upon submission of an acceptable progress report, including at least two photographs of the work conducted upon completion. To receive the final payment, grantees were required to submit a final narrative report and a working paper or publish an article in a national, regional, or international journal. The Research Office was responsible for supporting each grantee to progress through each stage of the research project. Payments were managed by the Accounting Office.

Figure 3: Monitoring and evaluation framework.

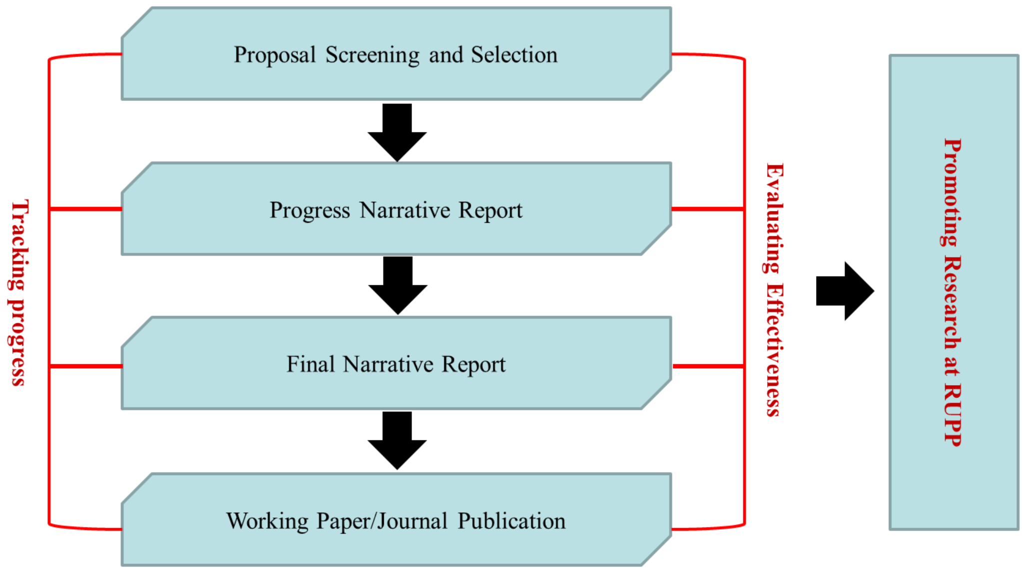
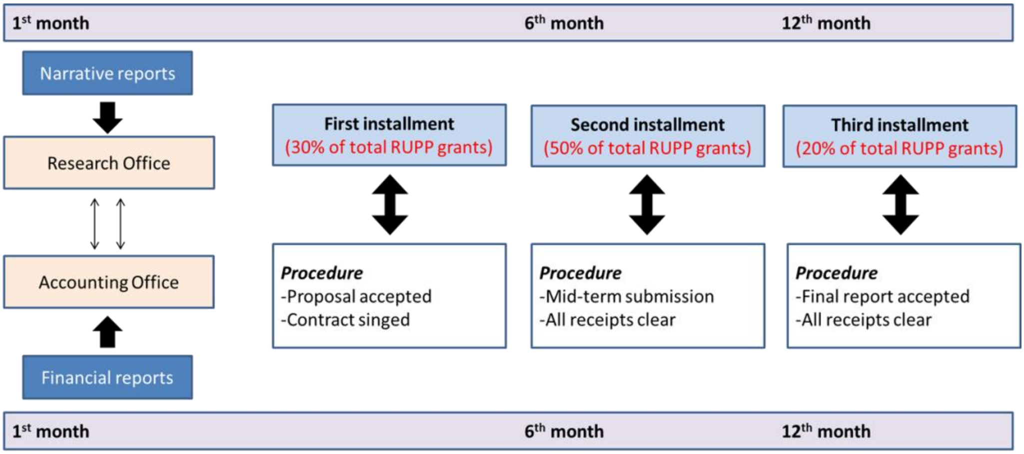


Figure 4. Monitoring and evaluation procedure.



Each grantee was required to adhere to a deadline for mid-term progress reports of 31 December 2017 and a final narrative report and working paper/journal publication, by 30 April 2018. A failure to satisfactorily meet these milestones or sufficiently respond to reviewer comments would result in the grant being discontinued.

Outcomes from the University Research Grants

Ideally, publication of the research conducted in an academic journal was the intended outcome for each URG. However, there were delays experienced in completing the field work for 2 of the 23 grants (see Table 3). In response, the Research Committee organized an ad-hoc meeting to allow these grantees discuss their progress and negotiate the acquittal of their URG through a working paper submitted at a later date (July 2018). After one year of the program, 11 academic papers had been published successfully in either a national, regional, or international journal. The output of the remaining ten URGs was compiled as a collection of working papers. The Research Office will continue to support these grantees to revise their work to a standard suitable for publication in a journal.

Table 3. The proportion of URGs which met the stated requirements.

Type of grant	**Project**	**Full acquittal**	**Achievement**
Large scale (US$ 5,000)	7	6	85.7%
Medium scale (US$ 3,000)	11	11	100.0%
Small scale (US$ 1,000)	5	4	93.1%

Table 4. Research published in journals not managed by RUPP

No.	Title, author, and journal	Level
1	Spoann, V., Fujiwara, T., Seng, B., & Lay, C. (2018). Municipal solid waste management: Constraints and opportunities to improve capacity of local government authorities of Phnom Penh Capital. *Waste Management & Research*, *36*(10), 985–992. https://doi.org/10.1177/0734242X18785722	International
2	Chun, B., Hieu, V. N., & Suon, S. (2018) 'Buddhist community work in Cambodia' *ASEAN Social Work Journal 2*(1) pp. 1-11.	Regional
3	Tao, N., Om, S., & Sot, V. (2018) 'Identifying the optimal mechanisms for the professional development of academic staff at the Royal University of Phnom Penh.' *Cambodia Education Review 2*(1) pp. 4-29.	National
4	Pang, S., & Khan, C. (2018) 'The Impact of a podcast project on learning outcomes: A case study of two content-based courses' *Cambodia Education Review 2*(1) pp. 31-51.	National
5	Keuk, C. N., & Monh, S. (2018) 'Reflective practice for pre-service Teachers of English Language: A case study at the Institute of Foreign Languages of the Royal University of Phnom Penh' *Cambodia Education Review 2*(1) pp. 52-80.	National
6	Soviphea, C., Nget, D., & Somchan, S. (2018) 'Improving student's speaking ability through the integration of Information and Communication Technology in English as a Foreign Language classrooms in Higher Education Institutions. *Cambodia Education Review 2*(1) pp. 81-107.	National

To support the publication of peer-reviewed research, 'Insight: Cambodia Journal of Basic and Applied Research' was established in 2018, published by the Royal University of Phnom Penh (RUPP).

Table 5: Journal articles published by RUPP

No.	Title, author, and journals	Level
1	Phoeurk, C., Tieng, S., Tan, S., Moeurng, S., Cheu, S., Chean, P. S., Hay, V., Say, C., Lim, L., & Kann, L. (2018). 'Prevalence and concentration of Escherichia coli and Salmonella species in fresh vegetables collected from different types of markets in Phnom Penh'. *Insight: Cambodia Journal of Basic and Applied Research, 1*(1), pp. 75-95.	National
2	Chanspheaktra, S. (2018) 'Simulating future trends in stormwater runoff related to climate and land use changes at a university campus'. *Insight: Cambodia Journal of Basic and Applied Research, 1*(1), pp. 48-74.	National
3	Soknet, S. (2018) 'Seasonal variation in the nitrate concentration of groundwater samples surrounding the Dangkor Municipal Solid Waste Landfill'. *Insight: Cambodia Journal of Basic and Applied Research, 1*(1), pp. 96-123.	National
4	Phauk, S. (2018) 'Preliminary research on insect diversity at Kulen Promtep Wildlife Sanctuary'. *Insight: Cambodia Journal of Basic and Applied Research, 1*(1), pp. 15-47.	National
5	Khan, L. (2018) 'An economic assessment of urban flooding in Cambodia: A case study of Phnom Penh'. *Insight: Cambodia Journal of Basic and Applied Research, 1*(1), pp. 124-148.	National

It is an academic, policy and practice-oriented journal, covering all aspects of engineering, science, linguistics, development and environment studies, and the social sciences and humanities. Manuscripts of academic or applied research that contribute to the social, economic, and environmental development of Cambodia, the Greater Mekong Sub-region, or the ASEAN, from either Cambodian or international authors are eligible for submission. Manuscripts outlining theories, conceptual frameworks, innovations, best practices and technologies from any discipline are welcomed. However, the journal prioritizes research focused on the content of courses provided by RUPP. The journal is bilingual and authors may submit a manuscript in either in English or Khmer, with the abstract published in both languages. Two issues are published each year: Issue 1 (January – June), and Issue 2 (July – December). Issue 1, Volume 1 features articles arising from research conducted with the support of five of the URGs awarded as part of the RUPP Faculty Research Fund and was published in December 2018.

A critical factor in successful implementation of the RUPP Faculty Research Fund pilot was an allocation of 40% of the total value of each grant as a payment to the researcher. This allocation was vital in enabling grantees to focus on the research activities outlined in their proposal, as they were compensated for time spent away from teaching activities. However, limitations were still experienced due to the need for the grantees to balance teaching schedules with research work. Furthermore, the capacity of some grantees to conduct research to an acceptable standard for journal publication is something that requires more attention, especially in regards to choosing an appropriate research methodology, data analysis, and report writing.

Conclusion

Investing in the research capacity of staff at RUPP was piloted through the provision of URGs. Through this pilot, the university has made progress toward the vision of being a leading research hub and think tank in Cambodia. Overall, the implementation of the first iteration of the RUPP Faculty Research Fund was successful, with majority of URGs leading to research being published in either national, regional or international journals and the remainder due to be published as working papers compiled by the RUPP Research Office. The findings from these publications are important and will lead to local case studies being integrated into the curriculum at RUPP. Moreover these resources will inform future research, planning and policy development in Cambodia. The diversity of the research output of the 23 grantees is a key strength of the initiative. Additional benefits include the development of a process by which the Research Office, Research Committee, and Accounting Office developed the capacity to manage research funding in line with the criteria applied to world university rankings. The allocation of 40% of the research grant as a payment to the grantee is critically important to the ongoing success of URGs. Enabling RUPP staff to fully integrate research activities into their professional development is consistent with RUPP's strategy. The university aims to allocate more funds in this manner and continue to investing in research capacity of the university.

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Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Book Review[3]: Phil Benson, 'Teaching and researching autonomy in language learning'. (Harlow, UK, Longman/Pearson Education, 2011, 283 pages, 123 USD (Hardcover)
ISBN-13: 978-1408205013

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To cite this article: Keuk, C.N. & Lim, C. (2019) [Review of the book *Teaching and researching autonomy in language learning*, by P. Benson]. *Cambodia Journal of Basic and Applied Research (CJBAR*), 1:1, 165–173

Phill Benson's thought-provoking book, *Teaching and researching autonomy*, provides important views about teaching and researching regarding learner autonomy in (language) classrooms. This book has illuminated educational policy makers, curriculum developers, managers, teachers and various other professionals who are concerned about developing learner autonomy with core principles about learner autonomy, practices of (language) learner autonomy, and research areas about (language) learner autonomy. The book comprises four sections, each of which consists of several chapters. Additional information such as quotes and explanations, short synopses of relevant concepts, and bibliographies of the relevant scholars have also been portrayed in each chapter to enhance readers' comprehension of the chapter.

[3]This book review is based on original contribution of author.

Learner autonomy is a fundamental component of lifelong learning (Gavrilyuk, 2015). It is a learning skill which has recently drawn serious attention from the Royal Government of Cambodia, especially the Ministry of Education Youth and Sport (MoEYS) in its deep reform of the education sector in Cambodia (MoEYS, 2004, 2015, 2018). In Cambodia, lifelong learning is a newly developing concept, and it has become known after the adaption of Sustainable Development Goals (SDGs) in 2015. One of the 17 goals of SDG, Goal 4 aims to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” by 2030. Holec (1981) defined learner autonomy as learners’ ability to account for their learning, and this notion of learner autonomy has been enhanced upon by various scholars, applied linguists, researchers, teachers, and other professionals who advocate promoting autonomous learning to empower learners with lifelong learning skills.

Section 1 of the book consists of six chapters. This section provides an overview of “learner autonomy” in various contexts, and how it is established in language classrooms. Chapter 1 describes an origin of learner autonomy; autonomy and self-access; autonomy and learning training; autonomy and individualization; and autonomy and independence. This chapter also focuses on why learner autonomy should or should not be adopted for teaching and learning. Benson also explains the two faces of learner autonomy, i.e., a rise of learner autonomy and the relation between education and employability.

In Chapter 2, Benson further explains learner autonomy beyond the scope of language education. First, the education reform, which has occurred almost everywhere around the globe, has brought about a change in the way teaching is conducted; that is, a move toward classroom-based approaches which foster autonomy. Second, Benson points out the emergence as well as the development of learner autonomy in different fields, such as adult education, the psychology of learning, and the philosophy of personal autonomy. This overview has assisted readers in conceptualizing learner autonomy appropriately before they further read subsequent chapters.

Chapter 3 reveals a clear conceptualization of learner autonomy, including dimensions of autonomy; versions of autonomy; measuring autonomy; and autonomy and culture. This chapter helps readers broaden their understanding about learner autonomy – students taking responsibility for their learning; that is, students determine objectives; define what they will learn and how they learn it; select methods and techniques for learning and monitoring the progress of learning; and evaluate what has been learned.

Chapters 4 and 5 discuss a concept of control which is "a natural attribute of learning" (Benson, 2011, p. 73) and its dimensions with references to substantial evidence of various research to create strong sustenance of learner autonomy. Benson argues that (adult) learners exercise control over learning of their desire and even without any particular training in self-directed learning. Chapter 4 explains the kind of control in terms of autonomy, encompassing self-management in learning; learner agendas in the classroom; control of psychological factors influencing learning; and seeds of autonomy. Chapter 5, moreover, discusses the dimensions of control in terms of control over learning management; control over cognitive processing; and control over learning content. Chapter 6 provides a brief conclusion of this first section, stating that the concept of learner autonomy has long been discussed and researched in the fields of education, psychology and philosophy. The evidence from the research related to autonomy could yield a learner autonomy framework that can be adopted for practices in classrooms.

Section 2 of the book focuses on the practices of learner autonomy. It comprises eight chapters (i.e., Chapters 7 to 14). This section aims to "explain how practitioners and researchers can better demonstrate the effectiveness of their work in the field of autonomy; describe the main areas of practice associated with autonomy in language learning; and discuss evidence for effectiveness within these areas of practice in terms of autonomy and better language learning" (Benson, 2011, p. 121).

In Chapter 7, Benson first distinguishes three essential terms such as 'autonomy' – a learner attribute; 'autonomous learning' – a mode of learning; and 'autonomous learning programmes' – educational practices designed to foster autonomy. Second, Benson introduces six different types of approaches which are used to develop learner autonomy. These approaches are resource-based approaches, technology-based approaches, learner-based approaches, classroom-based approaches, curriculum-based approaches, and teacher-based approaches. Each of these approaches is detailed in subsequent chapters.

Chapter 8 unfolds how learner autonomy is created and fostered through resource-based learning. This chapter provides learners with opportunities to self-organize and self-direct their learning. To help practitioners of learner autonomy achieve high potential practice of autonomy, Benson demonstrates various kinds of approaches that promote autonomous learning opportunities; that is, creating self-access centers, tandem learning, distance learning, self-instruction, and out-of-class learning. In this chapter, Benson also discusses factors that contribute to the effectiveness of the resource-based approaches to autonomous learning regarding collaboration in resource-based learning, structure and support in resource-based learning, and skills in resource-based learning.

Chapter 9 reveals the essential roles of technology in assisting learners in self-organizing and self-directing their learning. Benson discusses the roles of technology in promoting autonomous learning in terms of computer-assisted language learning (CALL) and the internet, which allow learners to manage time and learning more efficiently and effectively; access to available resources when needed for learning; manage reading and writing effectively; and a combination of learning and entertainment. Benson argues that using technology-based approaches to teaching and learning empowers learners with their control over learning regarding managing the learning process and allowing more extensive access to authentic target language sources.

Chapter 10 is about using learner-based approaches to promote autonomous learning. The learner-based approaches rely on "learners' development, or behavioural and psychological change within the learners themselves" (Benson, 2011, p. 154). In contrast to the resource-based and technology-based approaches, which seek to provide opportunities for learners' self-directed learning, the learner-based approaches promote learners' control over learning. Benson discusses some factors which have impacts on learners regarding autonomous learning. These factors include learning strategies that learners adopt to fulfill learning goals; the kinds of activities, especially task-based activities, which promote autonomous learning; learners' language proficiency; types of texts; language modality; contexts of learning; background knowledge; target language and learner characteristics.

Chapter 11 expands the opportunities for promoting autonomous learning through classroom-based approaches, i.e., involving learners in making decision on learning processes. Benson argues that creating a collaborative and supportive learning environment in a classroom is essential for learners to develop autonomy. Factors such as creating a classroom learning environment that is appropriate to learners' learning styles, fostering collaborative and motivational tasks, and providing opportunities to learners to freely respond to tasks are conducive to enhancing learners' autonomous learning. Benson points out a practical approach for properly assessing learners' learning outcomes using a formative assessment that evaluates learners' learning performances rather than following a traditional assessment approach – a summative assessment.

Chapter 12 further expands the opportunities for autonomous learning through promoting learners' participation in creating curriculum by making decisions on the course content and procedures of learning through working with their teachers. This chapter provides five principles based on Cotteral (2000) for a course design that promotes autonomous learning. This chapter also demonstrates evidence of the effectiveness of involving learners in developing curriculum because learners have opportunities to exercise their control over learning at a certain number of levels.

In Chapter 13, Benson discusses the significant roles of teachers in promoting autonomous learning. These roles include facilitators, helpers, coordinators, councilors, consultants, advisers, knowers and resource. Besides these essential roles of teachers in enhancing learner autonomy in the classroom, developing teacher autonomy through teacher professional development, teacher research, reflective practice, and action research, is necessary. Benson argues that changing and training teachers to become autonomous teachers is a fundamental step toward preparing and training learners to be autonomous learners.

Chapter 14 summarizes these six approaches, i.e., resource-based; technology-based; learner-based; teacher-based; classroom-based; and curriculum-based approaches, the combination of which contributes to promoting autonomous learning. However, as Benson argues in this chapter, for learner autonomy to be successfully and effectively developed, implemented, and fostered, it requires learners' will or desire to adopt a learner autonomy approach and teachers' willingness to modify ways of teaching and learning, which were teacher-dominated learning methods, to be one that promotes learners' self-organized and directed learning.

Following Section 2, which has demonstrated six approaches to developing, implementing and fostering learner autonomy as stated earlier, Section 3 of the book, comprising two sub-sections, first provides key areas for research or action research in the field of autonomy. Second, it demonstrates and showcases six important case studies undertaken to examine teachers' research activities on learner autonomy. Case study 1 examined how pre-service teachers and novice teachers in Hong Kong promoted autonomous learning among their students using out-of-class learning activities. Case study 2 examined how a self-organized language learning community developed autonomous learning. Case study 3 investigated learners' and teachers' satisfaction and attitude towards language advising or counselling within a self-directed skill. Case study 4 explored the practices of self-directed learning in the classroom. Case study 5 focused on the effectiveness of learner autonomy in enhancing learners' language proficiency. Case study 6 explored the experiences of high achieving self-directed learners and the effects that these high achieving independent learners' learning behaviour might have on their learning progress. These case studies are exempla for scholars, teachers, and other professionals to construct a research design appropriately to study the practices of autonomous learning.

Section 4 of the book provides useful resources for research and practices of learner autonomy. These resources include books, journals and newspapers, conferences and workshops, professional organizations, and various research journals which publish research related to autonomous learning.

This book, being three-in-one, i.e., focusing on relevant concepts about autonomous learning, fundamental approaches for developing autonomous learning, and potential areas for teachers' research or action research to promote learner autonomy as well as case studies of learner autonomy, is significant, yet practical, for educational policy makers, curriculum developers, managers, scholars, applied linguists, teachers and other professionals who seek to develop, implement and foster autonomous learning. Not only does this reader-friendly and thought-provoking book assist these concerned people in conceptualizing learner autonomy, but it also helps them create a learning environment, which follows resource-based; technology-based;

learner-based; teacher-based; classroom-based; and curriculum-based approaches, that allows autonomous learning activities to be adopted by the learners. Upon reading this book, they will be able to construct teaching models for practising learner autonomy as well as research designs for exploring the practices of learner autonomy in the classrooms to get better views of learner autonomy and practices of learner autonomy and enhance the quality of teaching.

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Instructions for Authors

About the Journal

Insight: Cambodia Journal of Basic and Applied Research was established in 2018 by the Royal University of Phnom Penh (RUPP). It is an academic, policy and practice-oriented journal, which covers all aspects of science and engineering, the social sciences and humanities, education, development studies, and languages. The publisher, RUPP, was founded in 1960 and is the oldest and one of the largest public universities in Cambodia. It has a full membership of the ASEAN University Network (AUN) and is considered to be Cambodia's flagship university in teaching, research, and community service. Academic or applied research manuscripts from within Cambodia; or from outside Cambodia but contributing to the social, economic, or environmental development of Cambodia, ASEAN, or the Greater Mekong Subregion may be submitted to the journal. The journal welcomes manuscripts from any discipline, where theories, concepts, innovations, new technologies, or best practices are introduced. However, the journal reserves the right to prioritize research focused on topics aligned with the courses offered at RUPP.

Frequency of Issue

Insight: Cambodia Journal of Basic and Applied Research is a bilingual journal, where manuscripts may be published in either English or Khmer. However, all manuscripts must have abstracts in both English and Khmer. Two issues of the journal are published each year:

- Issue 1: January-June

- Issue 2: July- December

Each volume will comprise one editorial, five research papers, one policy paper, and a book review.

Manuscripts Accepted

Natural Science, Science, and Engineering

- Original research paper (3,000 – 5,000 words, including references)
- Short policy paper (1,000–2,000 words, including references), and
- News (< 500 words)

Arts, Linguistic, Humanities, Social Science, Development Studies and Environment

- Original research paper (6,000 – 8,000 words, including references),
- Short policy paper (1,000 – 4,000 words, including references), and
- News (< 500 words).

Manuscript Submission and Evaluation

The journal editors warmly welcome your submissions. Papers sent for consideration should be submitted electronically in Word format to Dr Serey Sok at the Research Office of the Royal University of Phnom Penh (cjbar.rupp@gmail.com). Submissions should include: (1) a full paper, (2) a cover page, and (3) supplementary data (if required).

Peer Review Integrity

All manuscripts considered for publication will undergo a process of double-blind peer review by independent expert referees. An internal evaluation will occur before the peer review process. The editor will inform the author whether the manuscript has been accepted or rejected within one month of the completion of the peer-review process. In total, the internal evaluation and external peer-review process may take up to four months, whereby the result may be:

- **Accepted without changes**. If a manuscript is evaluated as "*Accepted without change*", it is published in its original form.
- **Accepted with minor changes**. If a manuscript is evaluated as "*Accepted with minor changes*", the editor will accept the submission on revision of some minor aspects of the paper.
- **Accepted with major changes**. If a manuscript is evaluated as "*Accepted with major changes*", it will require an additional external evaluation by the peer review team.
- **Rejected**. If a manuscript is evaluated as "*Rejected*", it will not be accepted for re-submission, regardless of how it is later revised.

When the author is notified of acceptance to the journal, the editor will forward comments from the two peer-reviewers for consideration. Where a manuscript requires changes, the author will be given 30 days to review the manuscript. The author may be offered one or more rounds of review to change the manuscript meet the minimum standards required for publication in the journal.

An original research paper may vary in structure based on specific requirements of the topic, or the disciplinary background of the author(s), in terms of experiments, surveys, case studies, and so on. However, authors will need to collect and analyze new data and conduct an original study. The paper should be based on analysis and interpretation of this data. The suggested structure for a paper in this category is as follows:

- Introduction,
- Conceptual framework/literature review,
- Methodology,
- Findings and Results,
- Discussion,
- Conclusion,
- References, and
- Supplementary Data (if required).

A book review is an analysis of a book, including its contents, style, and merit. A book review may be written as an opinion piece, summary, or scholarly review. The suggested structure for a book review is as follows:

- Introduction,
- Body (a review of the contents of the book),
- Analysis and evaluation,
- Conclusion, and
- References.

A short policy paper is a communication piece focusing on a specific policy issue, which provides clear recommendations for policymakers. It is generally a preliminary study, which is a precursor to an original research paper. A manuscript for a short policy paper should use the following structure:

- Abstract,
- Introduction,
- Research methodology,
- Results,

- Discussion,
- References, and
- Supplementary Data (if required).

A news item is a brief description of a research project and an outline of some preliminary results. This provides an opportunity for authors to disseminate important results quickly. A news item should adhere to the following structure:

- Introduction,
- Aims and objectives,
- Research methodology,
- Preliminary results (if relevant),
- Discussion, and
- References.

Referencing Style

Insight: Cambodia Journal of Basic and Applied Research (CJBAR) has adopted the American Psychological Association (APA) style as referencing style.

How to cite a book in APA style

Citing a book in print

APA format structure:

Author, A. (Year of Publication). *Title of work*. Publisher City, State: Publisher.

For example:

Finney, J. (1970). *Time and again*. New York, NY: Simon and Schuster.

Notes: When citing a book in APA, keep in mind:

- Capitalize the first letter of the first word of the title and any subtitles, as well as the first letter of any proper nouns.
- The full title of the book, including any subtitles, should be stated and *italicized*.

Citing an e-book from an e-reader

E-book is short for "electronic book." It is a digital version of a book that can be read on a computer, e-reader (Kindle, Nook, etc.), or other electronic device.

APA format structure:

Author, A. (Year of Publication). *Title of work* [E-Reader Version]. Retrieved from http://xxxx or DOI:xxxx

For example:

Eggers, D. (2008). *The circle* [Kindle Version], Retrieved from http://www.amazon.com/

Citing a book found in a database

APA format structure:

Author, A. (Year of Publication). *Title of work*. Retrieved from http://xxxx or DOI:xxxx

For example:

Sayre, Rebecca K., Devercelli, A.E., Neuman, M.J., & Wodon, Q. (2015). *Investment in early childhood development: Review of the world bank's recent experience*. DOI: 10.1596/978-1-4648-0403-8

Note: When citing an online book or e-book in APA, keep in mind:

- A **DOI** (digital object identifier) is an assigned number that helps link content to its location on the Internet. It is therefore important, if one is provided, to use it when creating a citation. All DOI numbers begin with a 10 and are separated by a slash.

How to reference a magazine in APA style

Citing a magazine article in print

APA format structure:

Author, A. (Year, month of Publication). Article title. *Magazine Title*, *Volume*(Issue), pp.-pp.

For example:

Tumulty, K. (2006, April). Should they stay or should they go? *Time*, *167*(15), 3-40.

Notes: When citing a magazine in APA, keep in mind:

- You can usually find the volume number with other publication information in the magazine;
- You can usually find page numbers in the bottom corner of a magazine article; and
- If you cannot locate an issue number, simply exclude it from the citation.

Citing a magazine article found online

APA format structure:

Author, A.A.. (Year, Month of Publication). Article title. *Magazine Title*, *Volume* (Issue), Retrieved from http://xxxx

For example:

Tumulty, K. (2006, April). Should they stay or should they go? *Time*, *167*(15) Retrieved from http://content.time.com/time/magazine/article/0,9171,1179361,00.html

Notes: When creating an online magazine citation, keep in mind:

- The volume and issue number aren't always on the same page as the article. Check other sections of the website before excluding these details from the citation.

How to reference a journal article in APA style

Citing a journal article in print

APA format structure:

Author, A. (Publication Year). Article title. *Periodical Title*, *Volume* (Issue), pp.-pp.

For example:

Nevin, A. (1990). The changing of teacher education special education. *Teacher education and special education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, *13* (3-4), 147-148.

Citing a journal article found online

APA format structure:

Author, A. (Publication Year). Article title. *Periodical Title*, *Volume* (Issue), pp.-pp. DOI:XX.XXXXX or Retrieved from journal URL

For example:

Jameson, J. (2013). E-Leadership in higher education: The fifth "age" of educational technology research. *British Journal of Educational Technology*, *44* (6), 889-915. DOI: 10.1111/bjet.12103

Notes: When creating an online journal article citation, keep in mind:

- APA does NOT require you to include the date of access/retrieval date or database information for electronic sources.

- You can use the URL of the journal homepage if the reference was retrieved online and there is no DOI assigned.

For example: Retrieved from http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)14678535;jsessionid=956132F3DE76EEB120577E99EE74CE9C.f04t01

- A **DOI** (digital object identifier) is an assigned number that helps link the content to its location on the Internet. It is important to use it on a citation if one is provided. All DOI numbers begin with a 10 and are separated by a slash.

How to reference a newspaper in APA style

Citing a newspaper article in print

APA format structure:

Author, A. (Year, Month Date of Publication). Article title. *Newspaper Title*, pp. xx-xx.

For example:

Rosenberg, G. (1997, March 31). Electronic discovery proves an effective legal weapon. *The New York Times*, p. D5.

Notes: When creating newspaper citation, keep in mind:

- Precede page numbers for newspaper articles with p. (for a single page) or pp. (for multiple pages).
- If an article appears on discontinuous pages, give all page numbers, and separate the numbers with a comma (e.g., pp. B1, B3, B5-B7).

How to cite a website in APA style

Citing a general website article with an author

APA format structure:

Author, A. (Year, Month Date of Publication). Article title. Retrieved from URL

For example:

Simmons, B. (2015, January 9). The tale of two Flaccos. Retrieved from http://grantland.com/the-triangle/the-tale-of-two-flaccos/

Citing a general website article without an author

APA format structure:

Article title. (Year, Month, Date of Publication). Retrieved from URL

For example:

Teen posed as doctor at West Palm Beach hospital: police. (2015, January 16). Retrieved from http://www.nbcmiami.com/news/local/Teen-Posed-as-Doctor-at-West-Palm-Beach-Hospital-Police-288810831.html

See details: http://www.bibme.org/citation-guide/apa/

Insight: Cambodia Journal of Basic and Applied Research, Volume 1 No. 1 (2019)

Insight

Cambodia Journal of Basic and Applied Research (CJBAR)

This journal has been approved by the Ministry of Information upon RUPP's request, No. 770/2018 RUPP, dated on 16 August 2018. The preparation and printing of this volume was generously supported by the Research Office of the Royal University of Phnom Penh, who also provided technical support in hosting, editing, and publishing the Cambodia Journal of Basic and Applied Research (CJBAR).

The Royal University of Phnom Penh (RUPP) is the oldest and the largest public university in Cambodia. It has contributed significantly to development of human resources for many sectors, especially to the training of teachers in high schools and other public servants. With respect to Cambodia's integration into the ASEAN Economic Community in 2015, the role of RUPP in furthering the scope of these achievements will need to be improved and strengthened accordingly. A situation analysis has shown that RUPP faces with considerable challenges in the further development of capacity in Cambodia, requiring comprehensive reform in terms of leadership and management, administration, and financing of the university. Our goal is to position the right people in the right place, improving teaching and learning methods, enhancing institutional capacity for research and development, and developing infrastructure and campus services. We believe this is essential for transforming RUPP into the flagship public university in Cambodia. Currently, 6% of our full-time staff hold doctoral degrees, 64% have master's degrees and 93% of our administration and finance staff are qualified to at least a bachelor degree level. We have almost 20,000 students and have more students receiving support from scholarships and fee waivers than any other large publicly funded university in Cambodia.

សាកលវិទ្យាល័យភូមិន្ទភ្នំពេញ Royal University of Phnom Penh

CJBAR ■Volume 01 ■Number 01 ■January-June 2019

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